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Marcheselli et al.

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(45) **Date of Patent: *Apr. 5, 2016**

(54) **SYSTEM AND METHOD FOR DETECTING, TRACKING AND COUNTING HUMAN OBJECTS OF INTEREST USING A COUNTING SYSTEM AND A DATA CAPTURE DEVICE**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Apr. 7, 2015**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
G06T 7/20 (2006.01)
G06K 9/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G06T 7/20*** (2013.01); ***G06F 17/30268*** (2013.01); ***G06K 9/00335*** (2013.01); ***G06K 9/00778*** (2013.01); ***G06T 7/0042*** (2013.01); ***G07C 9/00*** (2013.01); *G07C 9/00111* (2013.01)

(58) **Field of Classification Search**
CPC . G06K 9/00; G06K 9/00335; G06K 9/00362; G06K 9/00369; G06K 9/00771; G06K 9/00778; G06T 7/20; G06T 2207/10016; G06T 2207/30196; G06T 2207/30232; G07C 9/00; G07C 11/00
See application file for complete search history.

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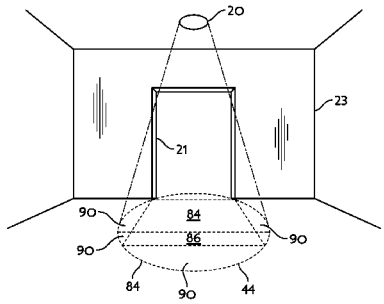
(74) *Attorney, Agent, or Firm* — Barnes & Thornburg LLP

(57) **ABSTRACT**

A method for counting and tracking defined objects includes the step of receiving subset data with a data capturing device, wherein the subset data is associated with defined objects and includes a unique identifier, an entry time, an exit time, and location data for each defined object. The method further includes the steps of receiving subset data at a counting system, counting the defined objects, tracking the defined objects, associating a location of a defined object with a predefined area, and/or generating path data by plotting X and Y coordinates for the defined object within the predefined area at sequential time periods.

13 Claims, 28 Drawing Sheets



(51) **Int. Cl.**

G07C 9/00	(2006.01)
G06F 17/30	(2006.01)
G06T 7/00	(2006.01)

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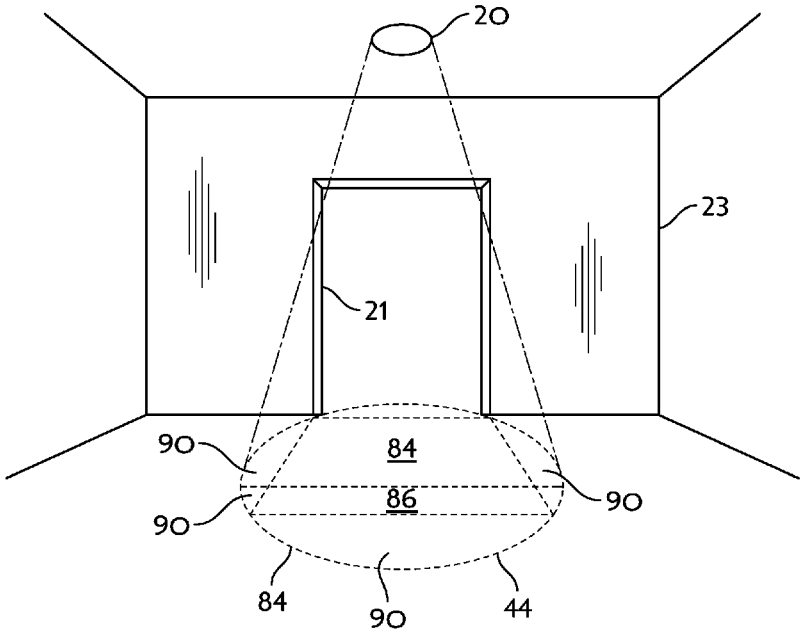
20
23
21
90
84
86
90
90
84
90
44

FIG. 1

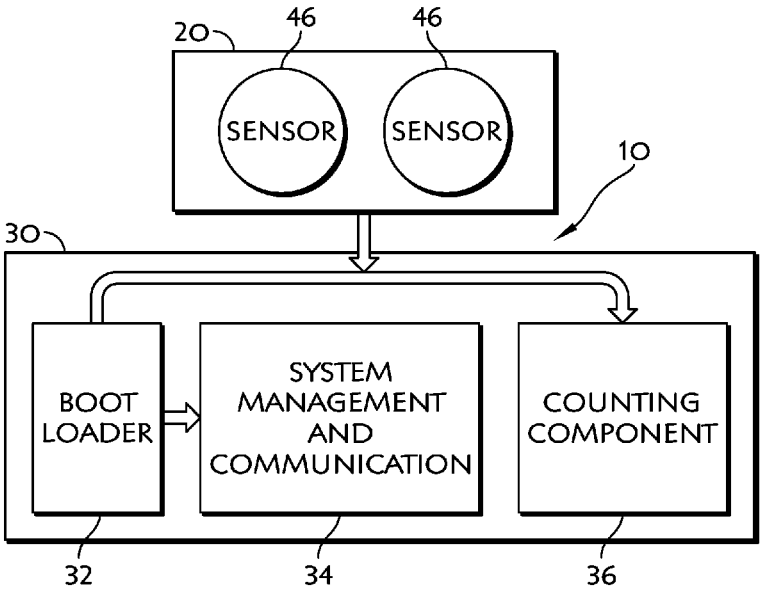
20
46
46
SENSOR
SENSOR
10
30
BOOT LOADER
SYSTEM MANAGEMENT AND COMMUNICATION
COUNTING COMPONENT
32
34
36

FIG. 2

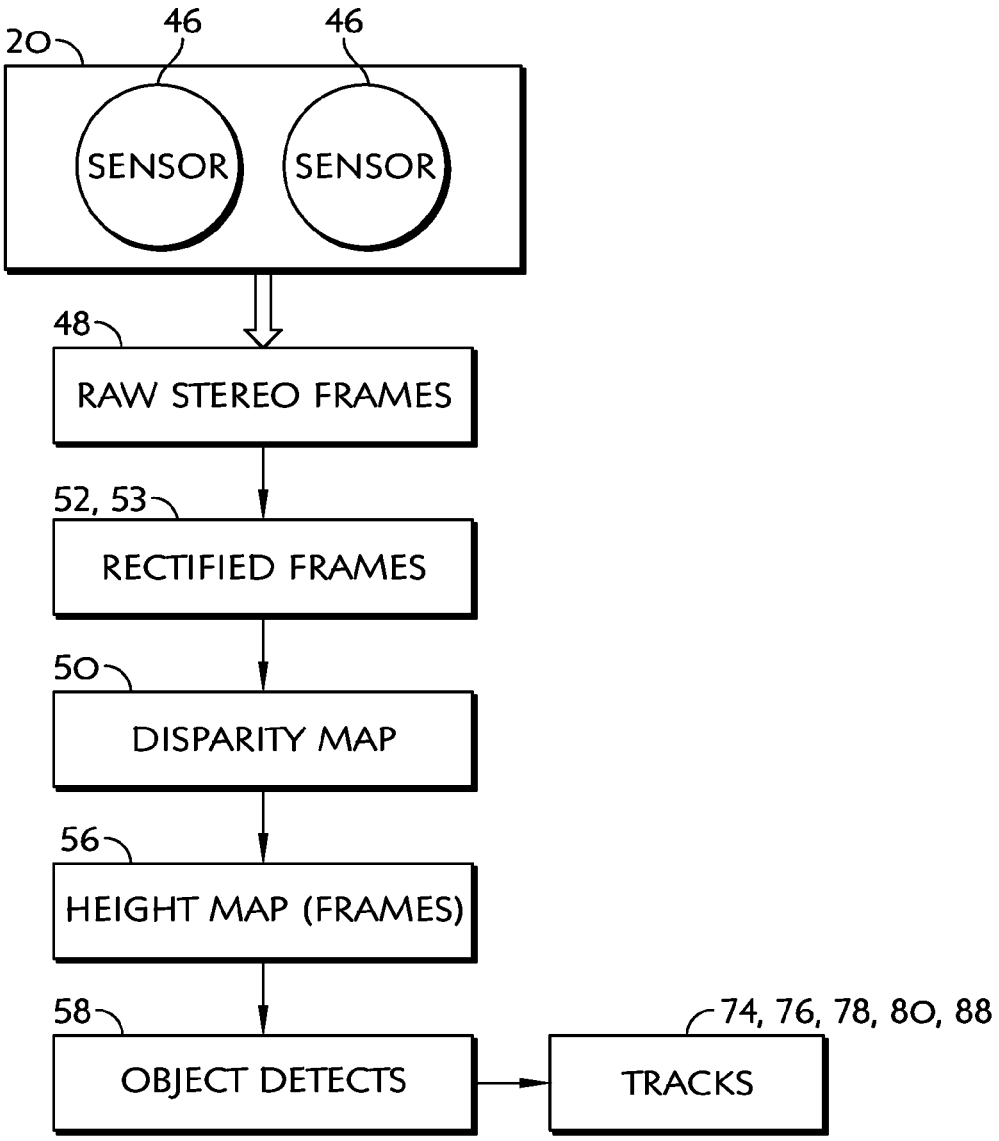
20
46
46
SENSOR
SENSOR
48
RAW STEREO FRAMES
52, 53
RECTIFIED FRAMES
50
DISPARITY MAP
56
HEIGHT MAP (FRAMES)
58
OBJECT DETECTS
74, 76, 78, 80, 88
TRACKS

FIG. 3

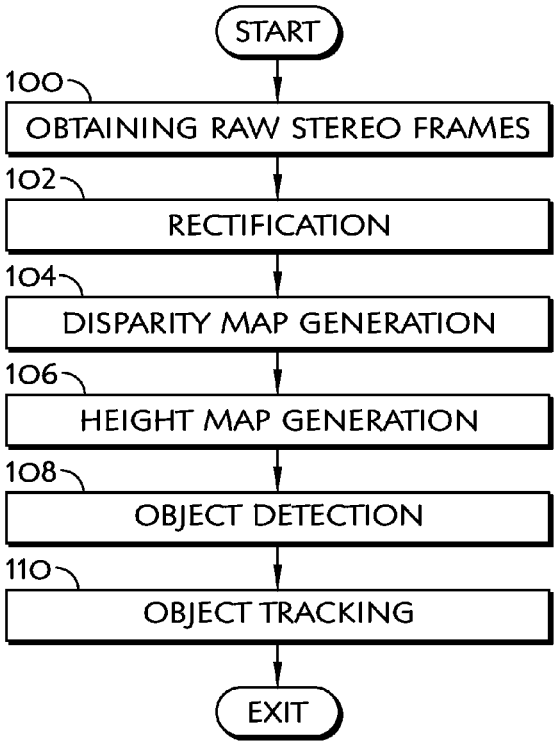
START
100
OBTAINING RAW STEREO FRAMES
102
RECTIFICATION
104
DISPARITY MAP GENERATION
106
HEIGHT MAP GENERATION
108
OBJECT DETECTION
110
OBJECT TRACKING
EXIT

FIG. 4

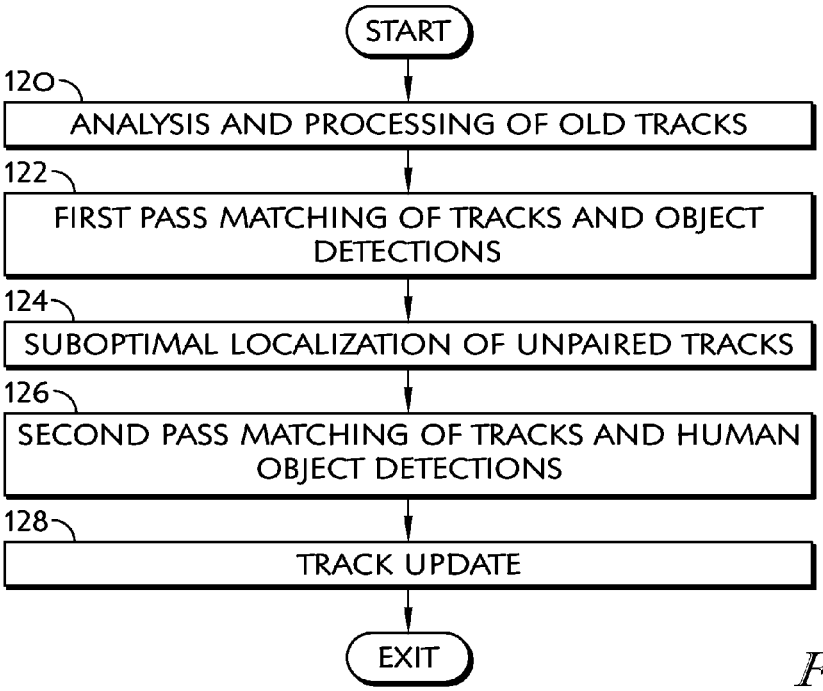
START
120
ANALYSIS AND PROCESSING OF OLD TRACKS
122
FIRST PASS MATCHING OF TRACKS AND OBJECT DETECTIONS
124
SUBOPTIMAL LOCALIZATION OF UNPAIRED TRACKS
126
SECOND PASS MATCHING OF TRACKS AND HUMAN OBJECT DETECTIONS
128
TRACK UPDATE
EXIT

FIG. 5

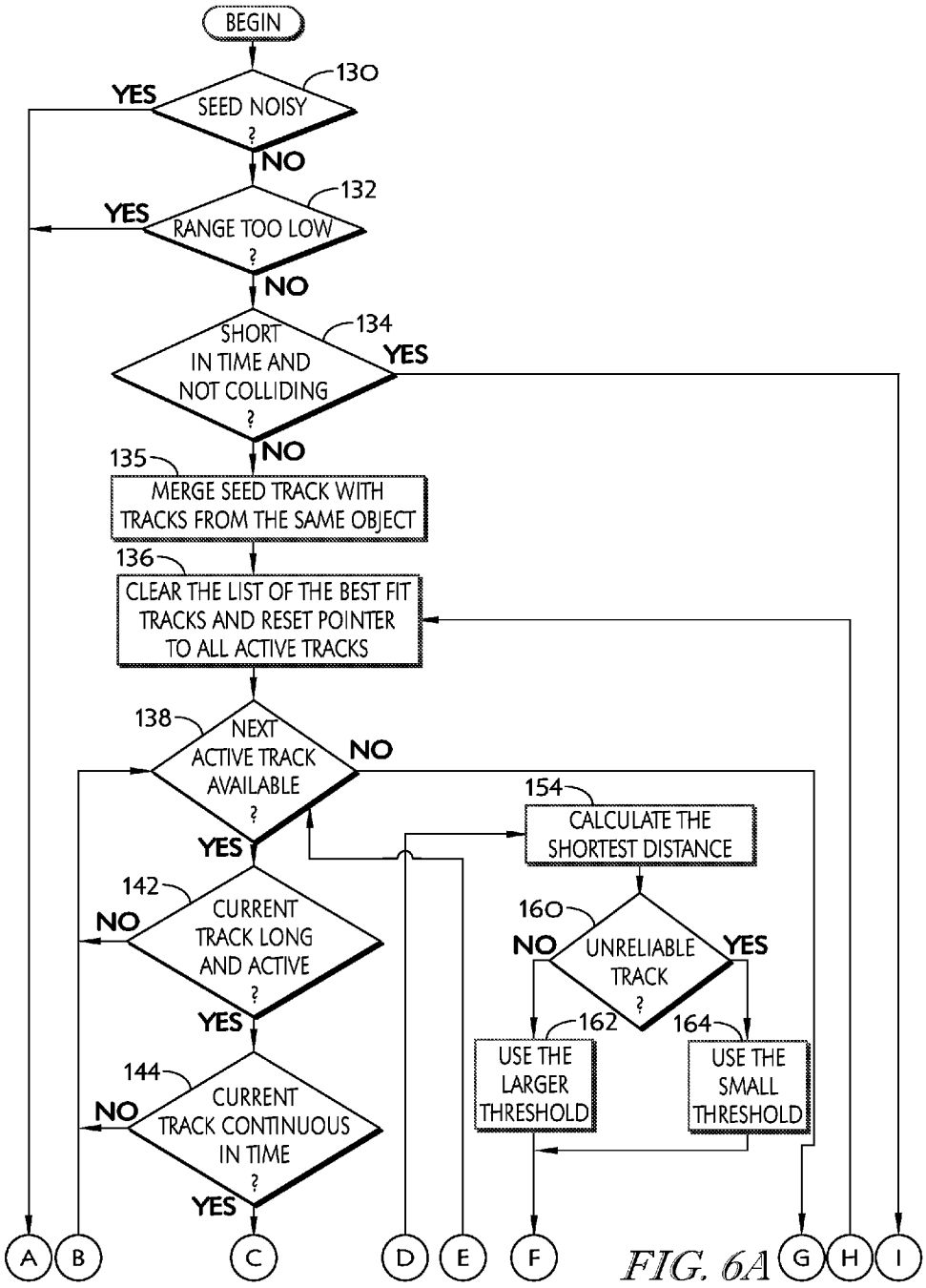
BEGIN
130
SEED NOISY ?
YES
NO
132
RANGE TOO LOW ?
YES
NO
134
SHORT IN TIME AND NOT COLLIDING ?
YES
NO
135
MERGE SEED TRACK WITH TRACKS FROM THE SAME OBJECT
136
CLEAR THE LIST OF THE BEST FIT TRACKS AND RESET POINTER TO ALL ACTIVE TRACKS
138
NEXT ACTIVE TRACK AVAILABLE ?
NO
YES
154
CALCULATE THE SHORTEST DISTANCE
142
CURRENT TRACK LONG AND ACTIVE ?
NO
YES
160
UNRELIABLE TRACK ?
NO
YES
162
USE THE LARGER THRESHOLD
164
USE THE SMALL THRESHOLD
144
CURRENT TRACK CONTINUOUS IN TIME ?
NO
YES
A
B
C
D
E
F
G
H
I

FIG. 6A

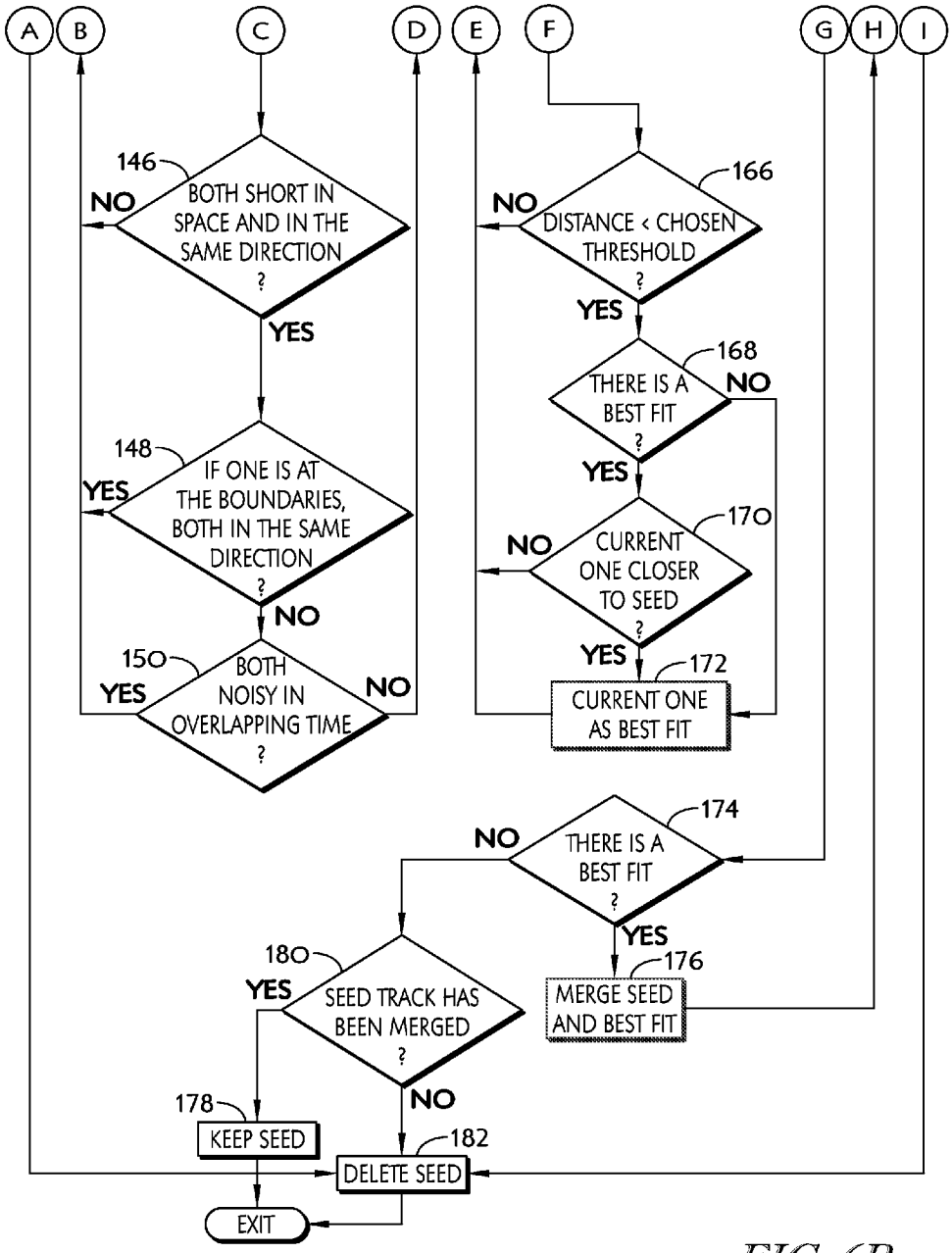
A
B
C
D
E
F
G
H
I
146
BOTH SHORT IN SPACE AND IN THE SAME DIRECTION ?
NO
YES
148
IF ONE IS AT THE BOUNDARIES, BOTH IN THE SAME DIRECTION ?
YES
NO
150
BOTH NOISY IN OVERLAPPING TIME ?
YES
NO
166
DISTANCE < CHOSEN THRESHOLD ?
NO
YES
168
THERE IS A BEST FIT ?
NO
YES
170
CURRENT ONE CLOSER TO SEED ?
NO
YES
172
CURRENT ONE AS BEST FIT
174
THERE IS A BEST FIT ?
NO
YES
176
MERGE SEED AND BEST FIT
180
SEED TRACK HAS BEEN MERGED ?
YES
NO
178
KEEP SEED
182
DELETE SEED
EXIT

FIG. 6B

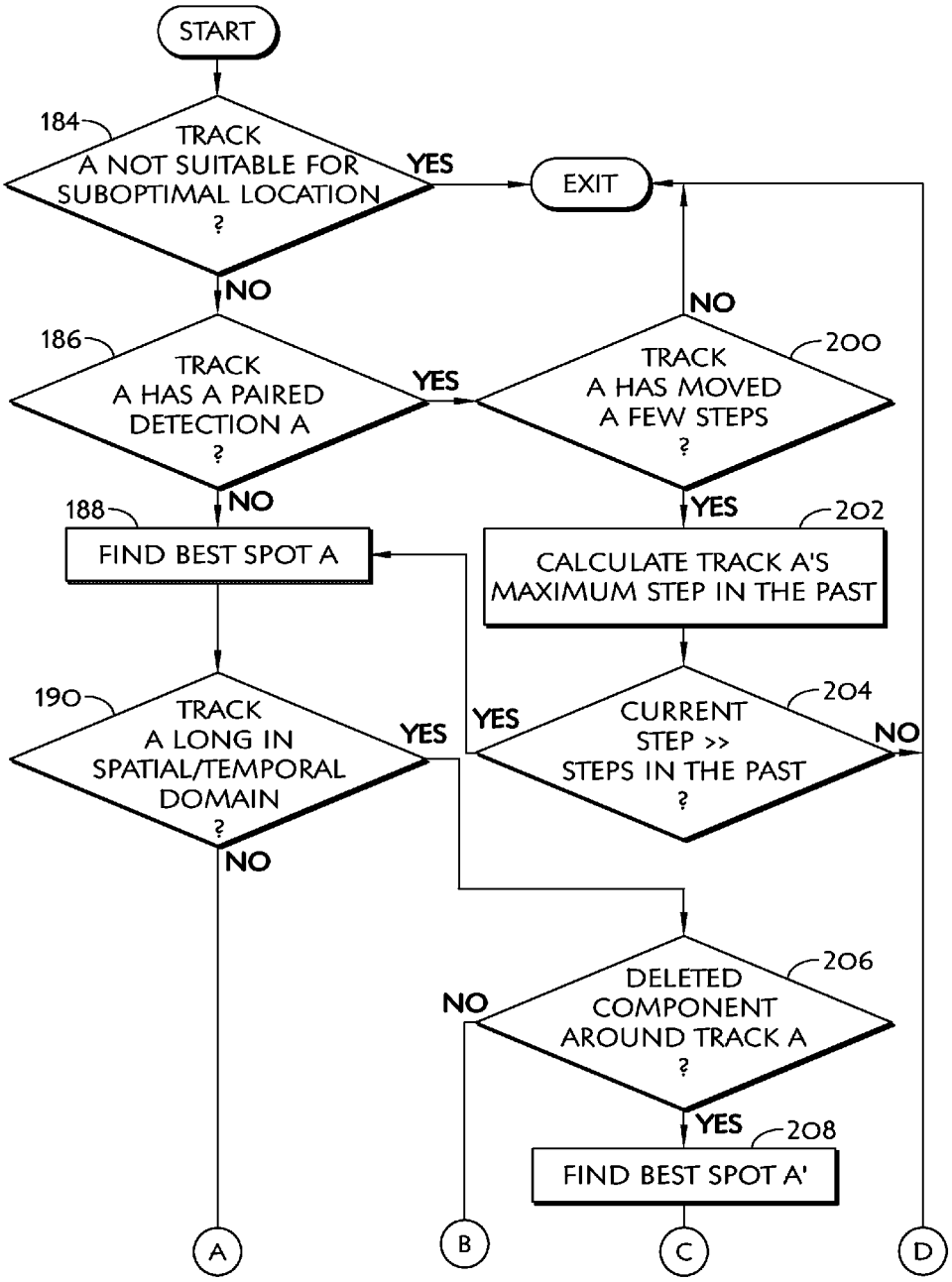
START
184
TRACK A NOT SUITABLE FOR SUBOPTIMAL LOCATION ?
YES
EXIT
NO
186
TRACK A HAS A PAIRED DETECTION A ?
YES
NO
200
TRACK A HAS MOVED A FEW STEPS ?
NO
YES
188
FIND BEST SPOT A
202
CALCULATE TRACK A'S MAXIMUM STEP IN THE PAST
190
TRACK A LONG IN SPATIAL/TEMPORAL DOMAIN ?
YES
NO
204
CURRENT STEP >> STEPS IN THE PAST ?
YES
NO
206
DELETED COMPONENT AROUND TRACK A ?
NO
YES
208
FIND BEST SPOT A'
A
B
C
D

FIG. 7A

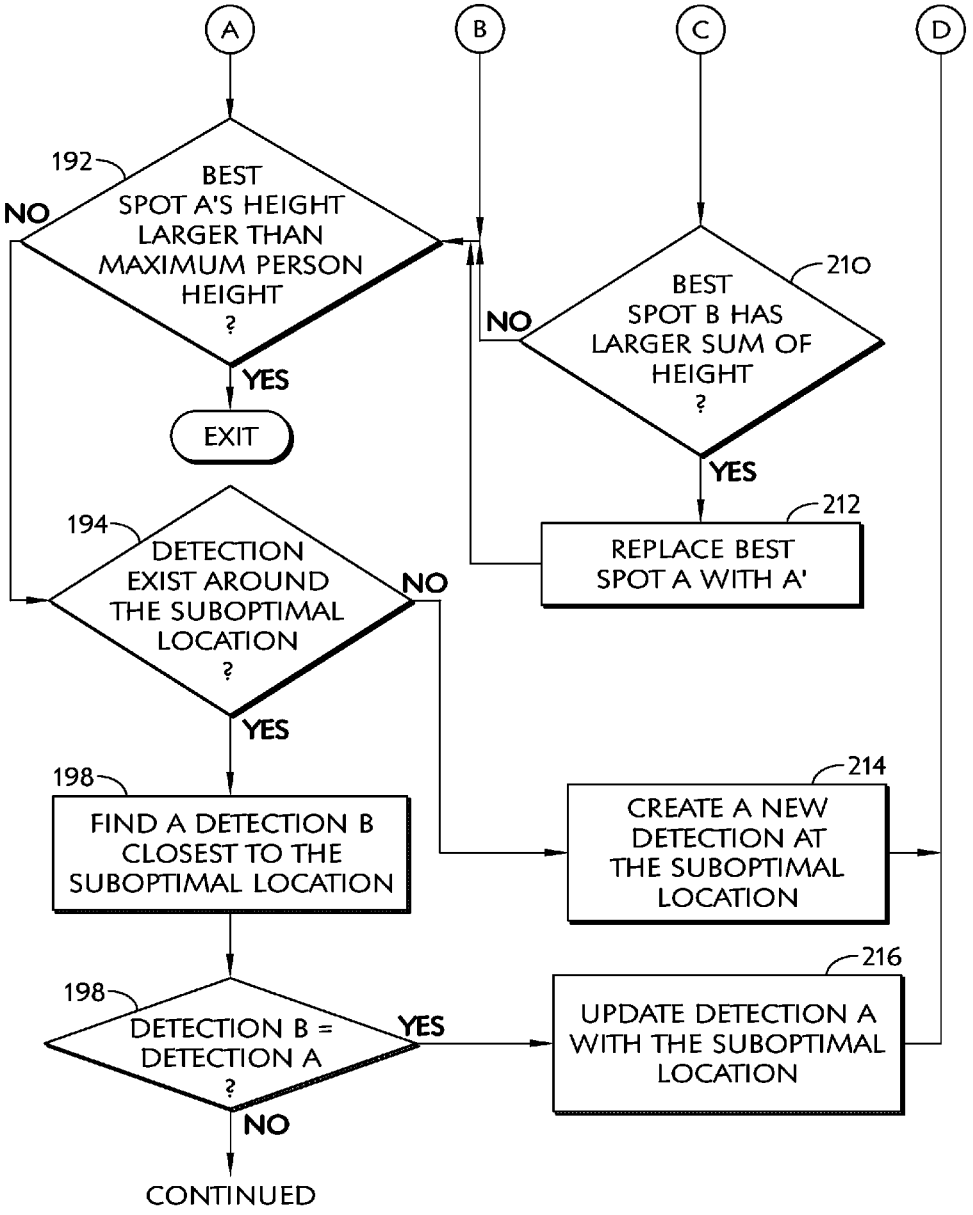
A
B
C
D
192
BEST SPOT A'S HEIGHT LARGER THAN MAXIMUM PERSON HEIGHT ?
NO
YES
EXIT
210
BEST SPOT B HAS LARGER SUM OF HEIGHT ?
NO
YES
212
REPLACE BEST SPOT A WITH A'
194
DETECTION EXIST AROUND THE SUBOPTIMAL LOCATION ?
NO
YES
198
FIND A DETECTION B CLOSEST TO THE SUBOPTIMAL LOCATION
214
CREATE A NEW DETECTION AT THE SUBOPTIMAL LOCATION
198
DETECTION B = DETECTION A ?
YES
NO
216
UPDATE DETECTION A WITH THE SUBOPTIMAL LOCATION
CONTINUED

FIG. 7B

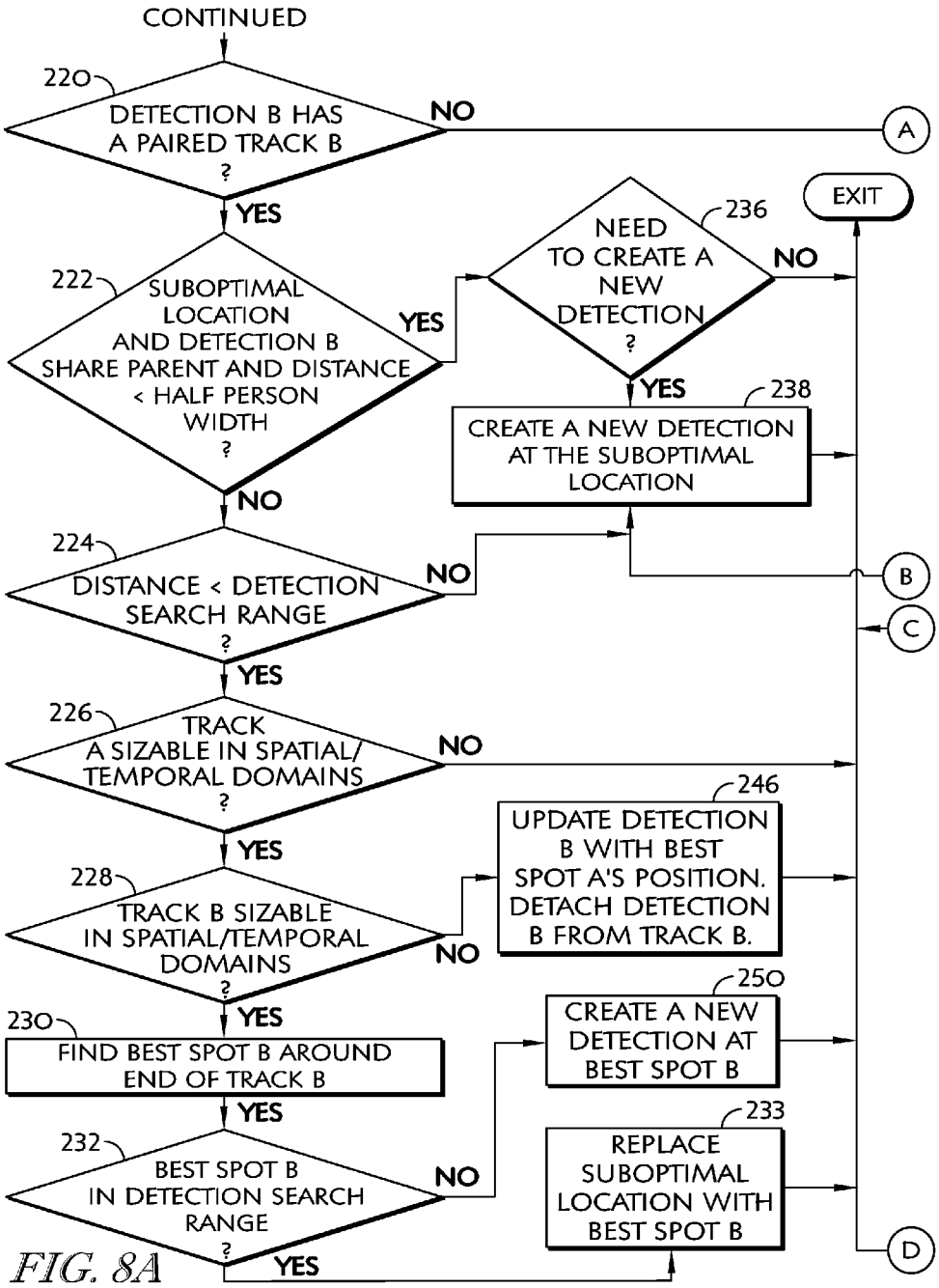
CONTINUED
220
DETECTION B HAS A PAIRED TRACK B ?
NO
A
YES
222
SUBOPTIMAL LOCATION AND DETECTION B SHARE PARENT AND DISTANCE < HALF PERSON WIDTH ?
YES
236
NEED TO CREATE A NEW DETECTION ?
NO
EXIT
YES
238
CREATE A NEW DETECTION AT THE SUBOPTIMAL LOCATION
NO
224
DISTANCE < DETECTION SEARCH RANGE ?
NO
B
C
YES
226
TRACK A SIZABLE IN SPATIAL/ TEMPORAL DOMAINS ?
NO
246
UPDATE DETECTION B WITH BEST SPOT A'S POSITION. DETACH DETECTION B FROM TRACK B.
YES
228
TRACK B SIZABLE IN SPATIAL/TEMPORAL DOMAINS ?
NO
250
CREATE A NEW DETECTION AT BEST SPOT B
YES
230
FIND BEST SPOT B AROUND END OF TRACK B
YES
233
REPLACE SUBOPTIMAL LOCATION WITH BEST SPOT B
232
BEST SPOT B IN DETECTION SEARCH RANGE ?
NO
YES
D

FIG. 8A

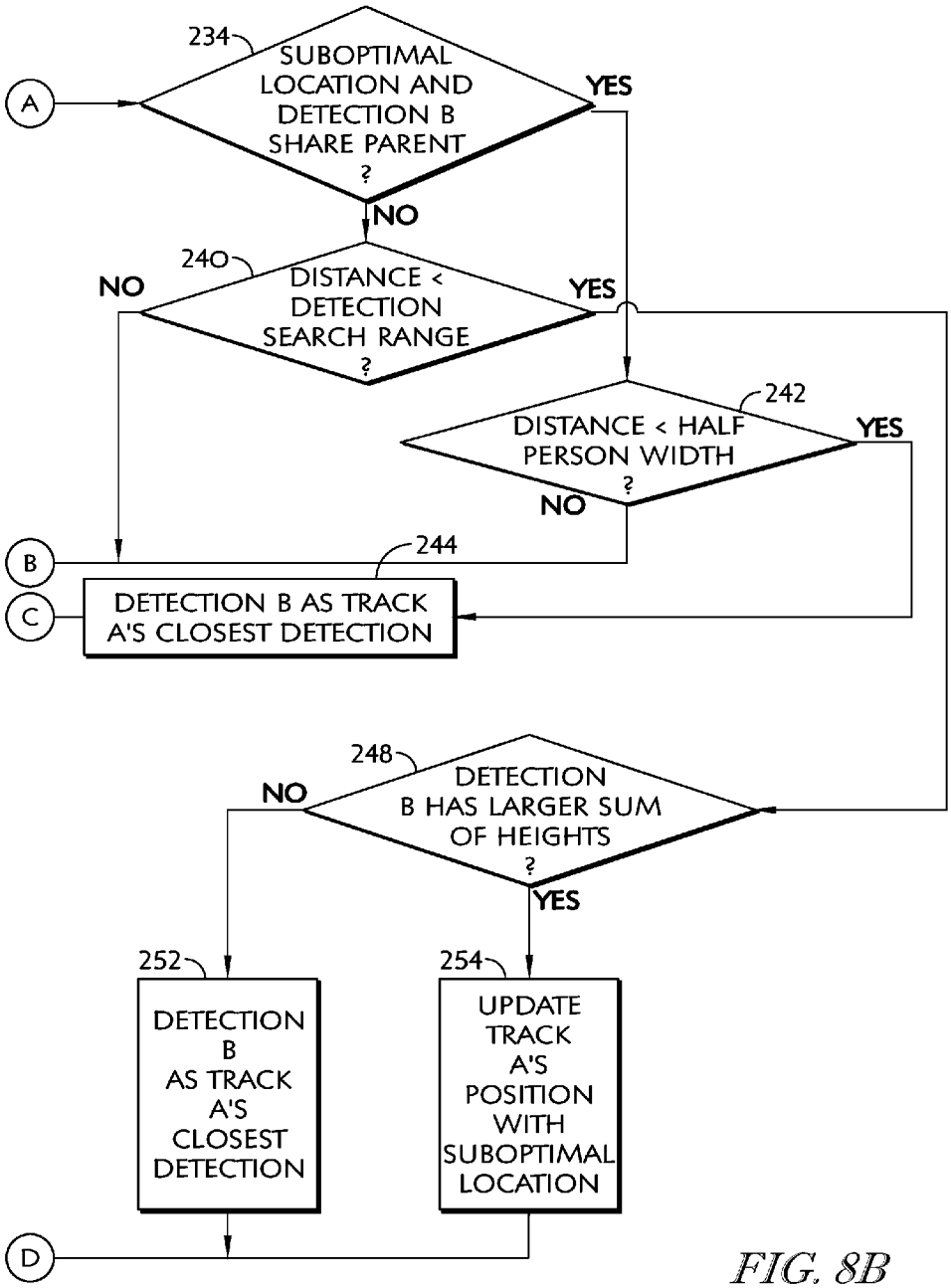
234
SUBOPTIMAL LOCATION AND DETECTION B SHARE PARENT ?
A
YES
NO
240
DISTANCE < DETECTION SEARCH RANGE ?
NO
YES
242
DISTANCE < HALF PERSON WIDTH ?
YES
NO
B
244
C
DETECTION B AS TRACK A'S CLOSEST DETECTION
248
DETECTION B HAS LARGER SUM OF HEIGHTS ?
NO
YES
252
DETECTION B AS TRACK A'S CLOSEST DETECTION
254
UPDATE TRACK A'S POSITION WITH SUBOPTIMAL LOCATION
D

FIG. 8B

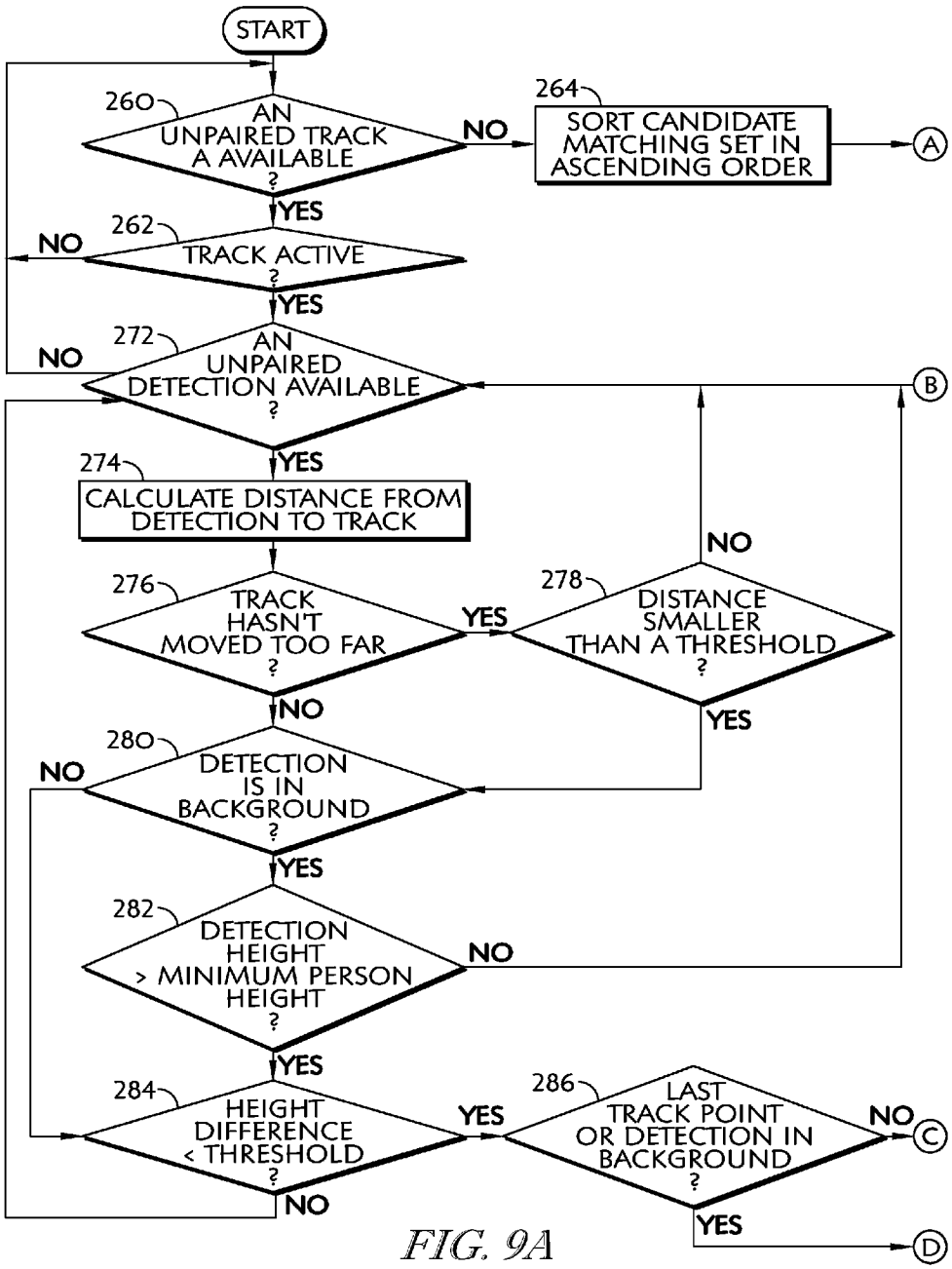
START
260
AN UNPAIRED TRACK A AVAILABLE ?
NO
264
SORT CANDIDATE MATCHING SET IN ASCENDING ORDER
A
YES
262
TRACK ACTIVE ?
NO
YES
272
AN UNPAIRED DETECTION AVAILABLE ?
NO
B
YES
274
CALCULATE DISTANCE FROM DETECTION TO TRACK
NO
276
TRACK HASN'T MOVED TOO FAR ?
YES
278
DISTANCE SMALLER THAN A THRESHOLD ?
NO
YES
280
DETECTION IS IN BACKGROUND ?
NO
YES
282
DETECTION HEIGHT > MINIMUM PERSON HEIGHT ?
NO
YES
284
HEIGHT DIFFERENCE < THRESHOLD ?
YES
286
LAST TRACK POINT OR DETECTION IN BACKGROUND ?
NO
C
NO
YES
D

FIG. 9A

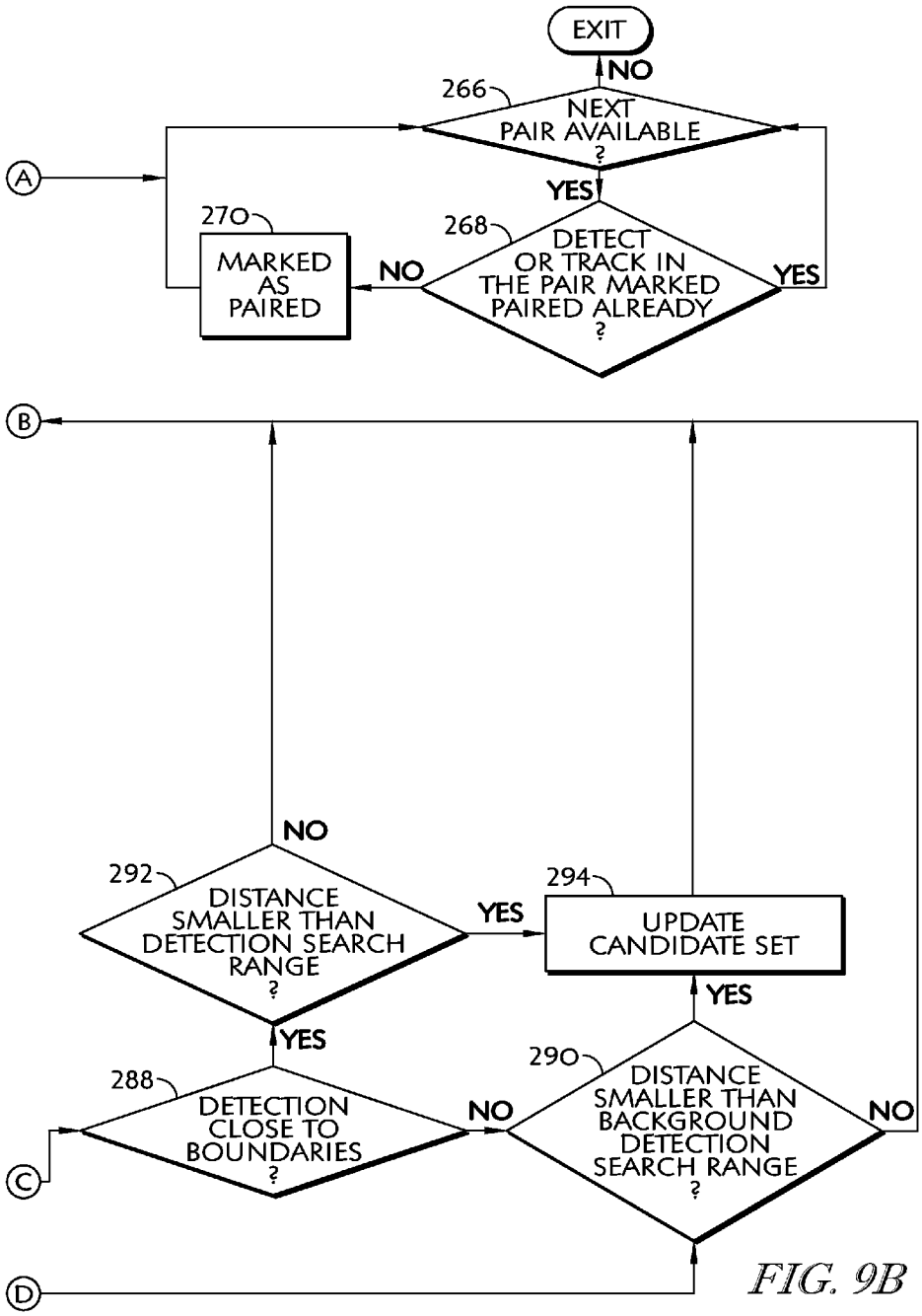
EXIT
NO
266
NEXT PAIR AVAILABLE ?
A
YES
270
MARKED AS PAIRED
NO
268
DETECT OR TRACK IN THE PAIR MARKED PAIRED ALREADY ?
YES
B
NO
292
DISTANCE SMALLER THAN DETECTION SEARCH RANGE ?
YES
294
UPDATE CANDIDATE SET
YES
YES
288
DETECTION CLOSE TO BOUNDARIES ?
NO
290
DISTANCE SMALLER THAN BACKGROUND DETECTION SEARCH RANGE ?
NO
C
D

FIG. 9B

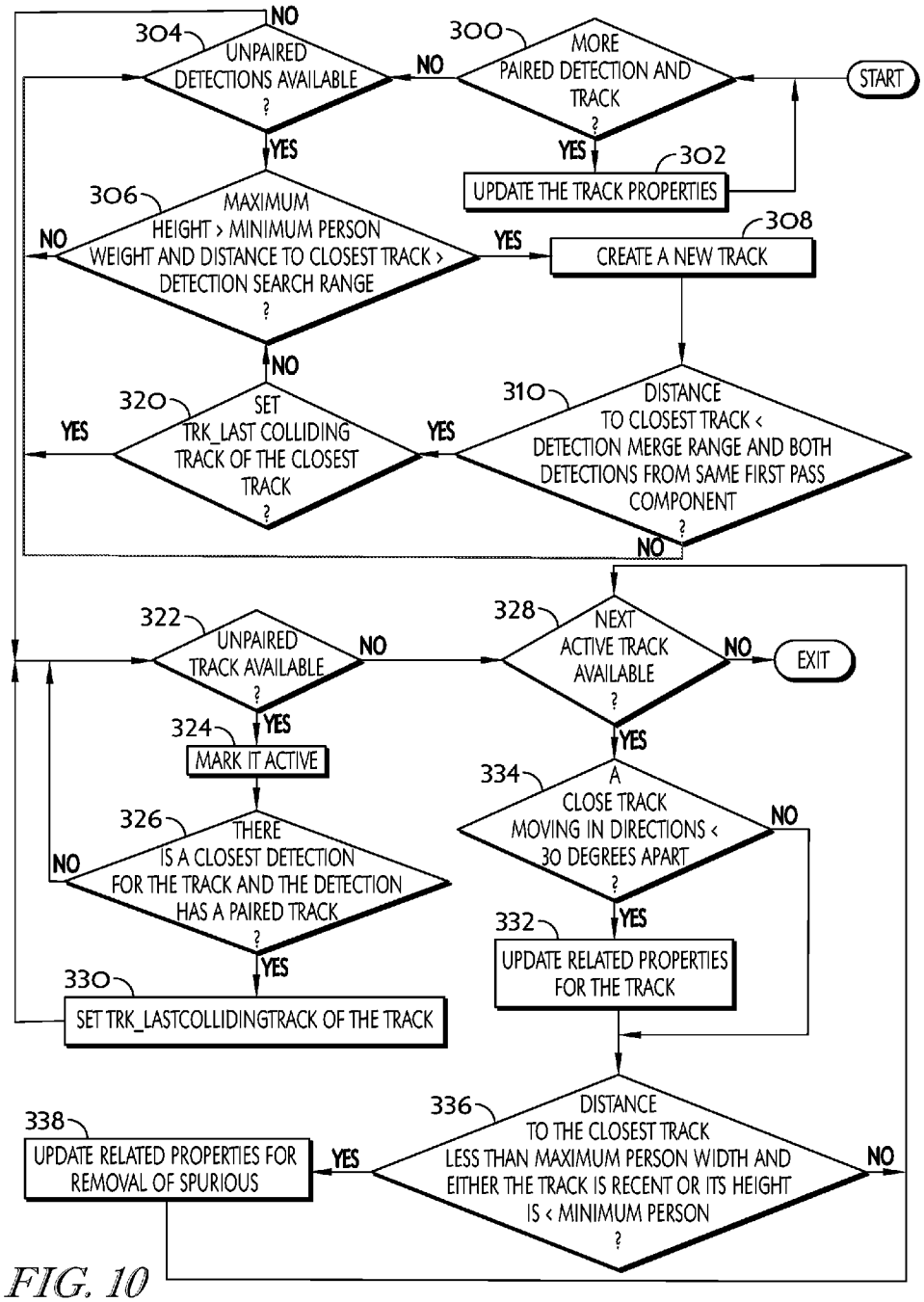
START
300
MORE PAIRED DETECTION AND TRACK ?
NO
YES
302
UPDATE THE TRACK PROPERTIES
304
UNPAIRED DETECTIONS AVAILABLE ?
NO
YES
306
MAXIMUM HEIGHT > MINIMUM PERSON WEIGHT AND DISTANCE TO CLOSEST TRACK > DETECTION SEARCH RANGE ?
NO
YES
308
CREATE A NEW TRACK
310
DISTANCE TO CLOSEST TRACK < DETECTION MERGE RANGE AND BOTH DETECTIONS FROM SAME FIRST PASS COMPONENT ?
YES
NO
320
SET TRK_LAST COLLIDING TRACK OF THE CLOSEST TRACK ?
YES
NO
322
UNPAIRED TRACK AVAILABLE ?
NO
YES
324
MARK IT ACTIVE
326
THERE IS A CLOSEST DETECTION FOR THE TRACK AND THE DETECTION HAS A PAIRED TRACK ?
NO
YES
330
SET TRK_LASTCOLLIDINGTRACK OF THE TRACK
328
NEXT ACTIVE TRACK AVAILABLE ?
NO
EXIT
YES
334
A CLOSE TRACK MOVING IN DIRECTIONS < 30 DEGREES APART ?
NO
YES
332
UPDATE RELATED PROPERTIES FOR THE TRACK
336
DISTANCE TO THE CLOSEST TRACK LESS THAN MAXIMUM PERSON WIDTH AND EITHER THE TRACK IS RECENT OR ITS HEIGHT IS < MINIMUM PERSON ?
YES
NO
338
UPDATE RELATED PROPERTIES FOR REMOVAL OF SPURIOUS

FIG. 10

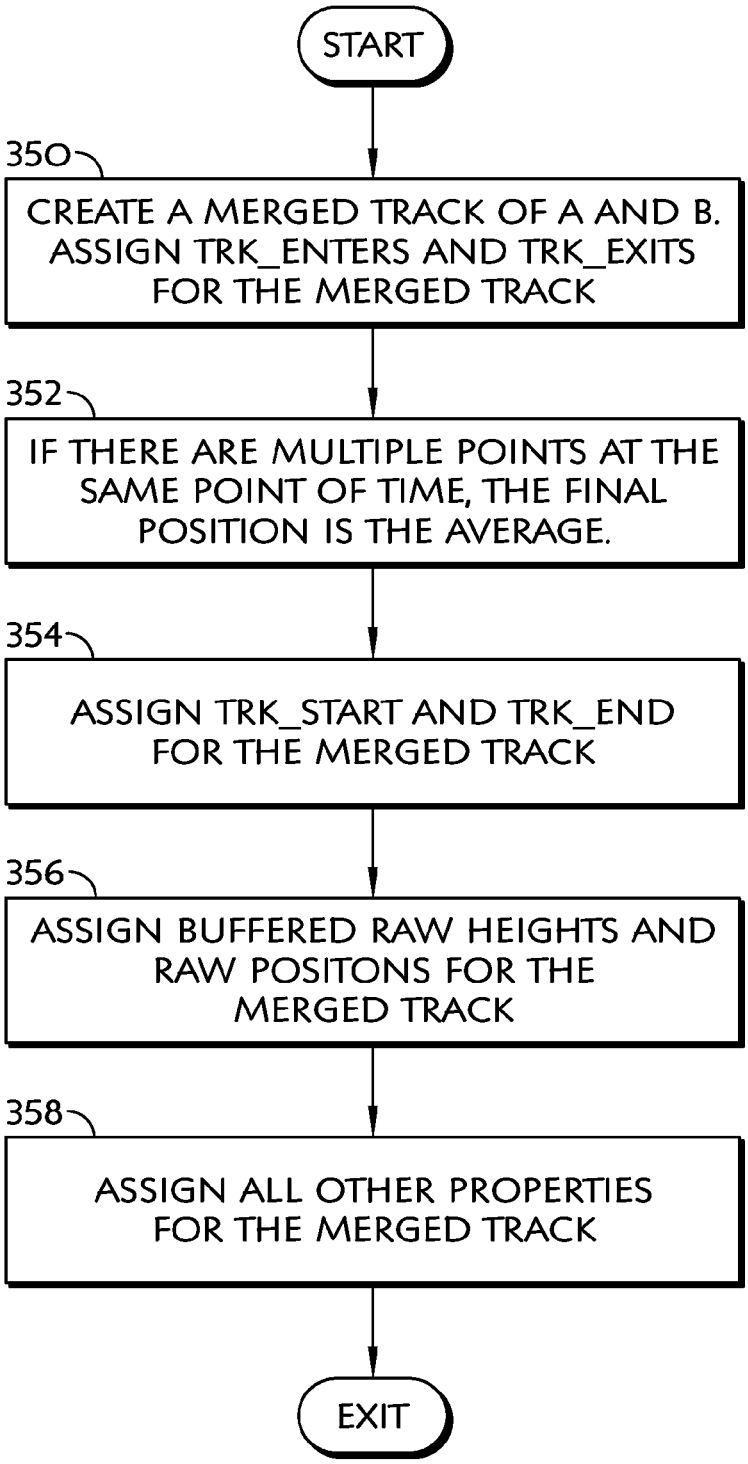
START
350
CREATE A MERGED TRACK OF A AND B. ASSIGN TRK_ENTERS AND TRK_EXITS FOR THE MERGED TRACK
352
IF THERE ARE MULTIPLE POINTS AT THE SAME POINT OF TIME, THE FINAL POSITION IS THE AVERAGE.
354
ASSIGN TRK_START AND TRK_END FOR THE MERGED TRACK
356
ASSIGN BUFFERED RAW HEIGHTS AND RAW POSITONS FOR THE MERGED TRACK
358
ASSIGN ALL OTHER PROPERTIES FOR THE MERGED TRACK
EXIT

FIG. 11

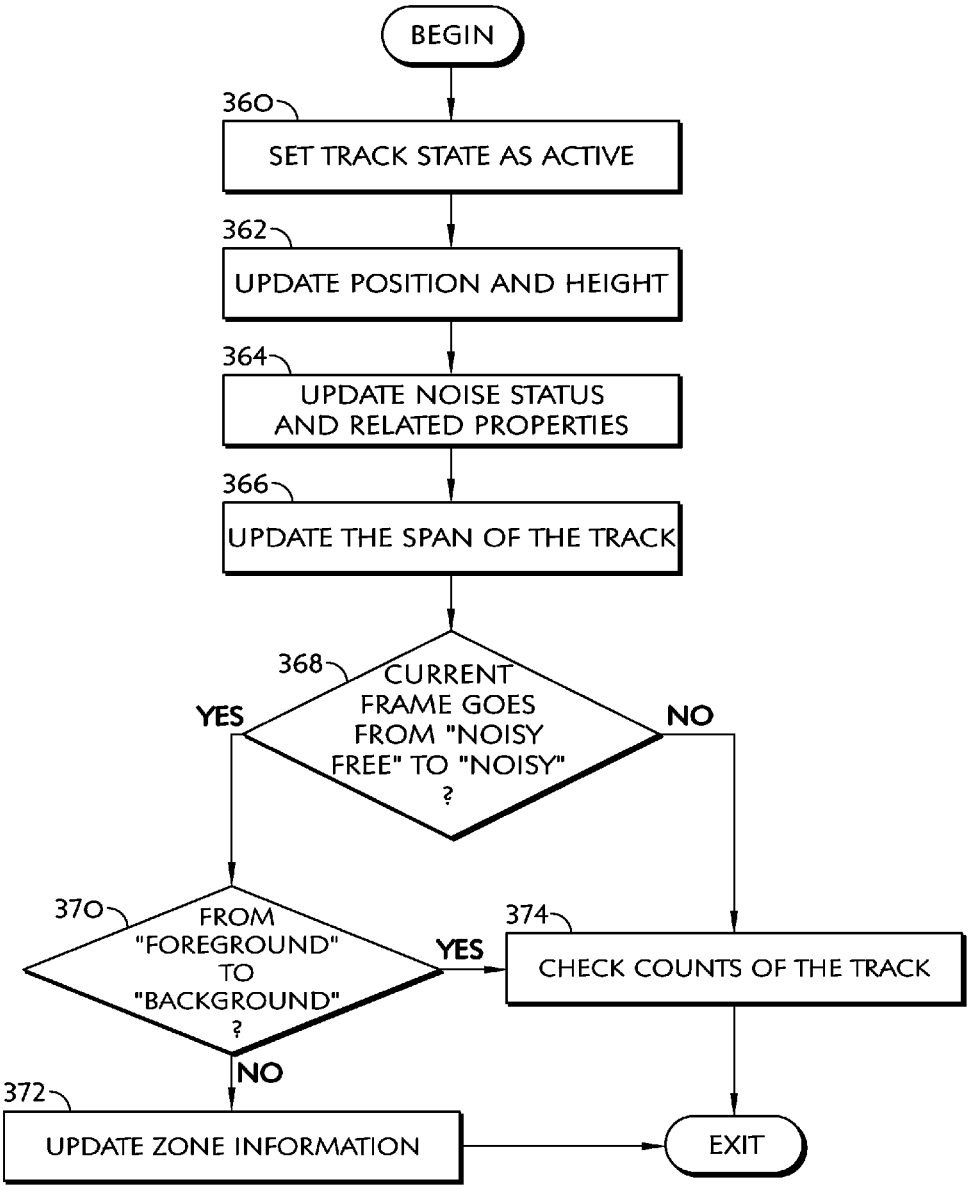
BEGIN
360
SET TRACK STATE AS ACTIVE
362
UPDATE POSITION AND HEIGHT
364
UPDATE NOISE STATUS AND RELATED PROPERTIES
366
UPDATE THE SPAN OF THE TRACK
368
CURRENT FRAME GOES FROM "NOISY FREE" TO "NOISY" ?
YES
NO
370
FROM "FOREGROUND" TO "BACKGROUND" ?
YES
NO
374
CHECK COUNTS OF THE TRACK
372
UPDATE ZONE INFORMATION
EXIT

FIG. 12

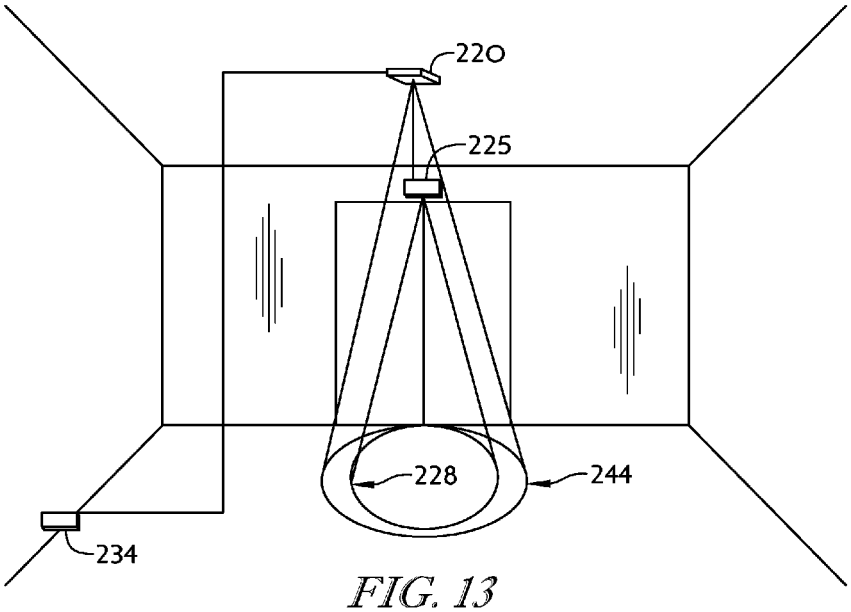
220
225
228
244
234

FIG. 13

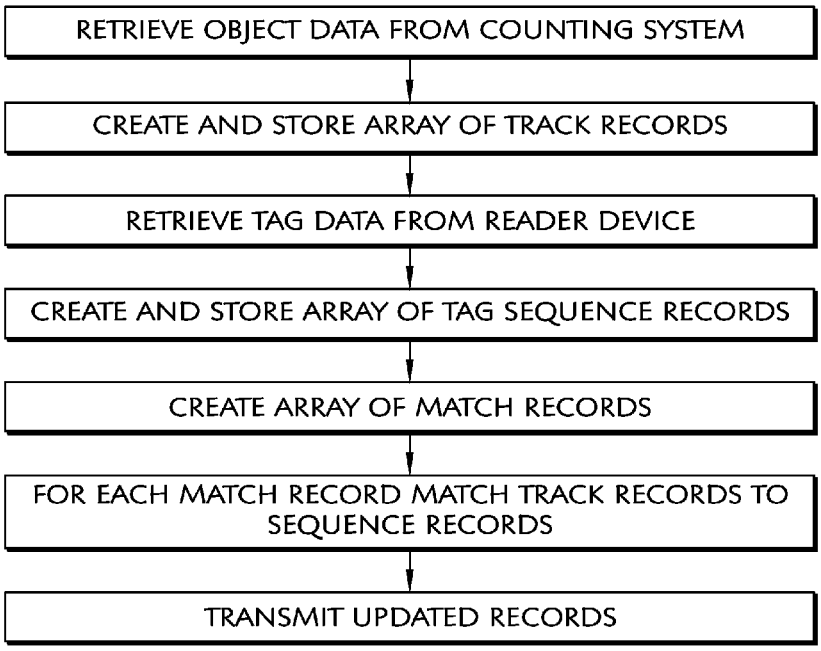
RETRIEVE OBJECT DATA FROM COUNTING SYSTEM
CREATE AND STORE ARRAY OF TRACK RECORDS
RETRIEVE TAG DATA FROM READER DEVICE
CREATE AND STORE ARRAY OF TAG SEQUENCE RECORDS
CREATE ARRAY OF MATCH RECORDS
FOR EACH MATCH RECORD MATCH TRACK RECORDS TO SEQUENCE RECORDS
TRANSMIT UPDATED RECORDS

FIG. 14

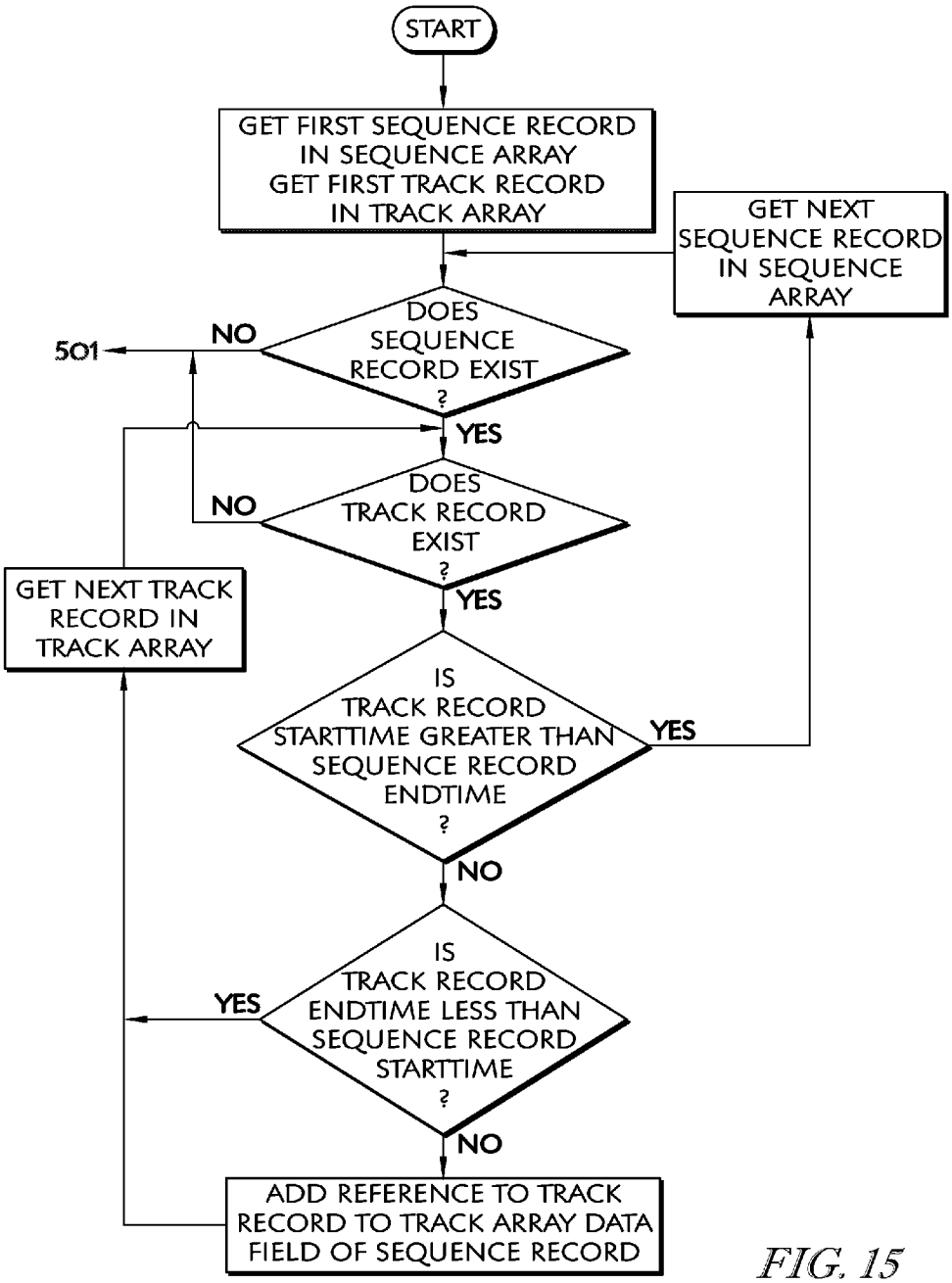
START
GET FIRST SEQUENCE RECORD IN SEQUENCE ARRAY GET FIRST TRACK RECORD IN TRACK ARRAY
GET NEXT SEQUENCE RECORD IN SEQUENCE ARRAY
DOES SEQUENCE RECORD EXIST ?
NO
501
YES
DOES TRACK RECORD EXIST ?
NO
YES
GET NEXT TRACK RECORD IN TRACK ARRAY
IS TRACK RECORD STARTTIME GREATER THAN SEQUENCE RECORD ENDTIME ?
YES
NO
IS TRACK RECORD ENDTIME LESS THAN SEQUENCE RECORD STARTTIME ?
YES
NO
ADD REFERENCE TO TRACK RECORD TO TRACK ARRAY DATA FIELD OF SEQUENCE RECORD

FIG. 15

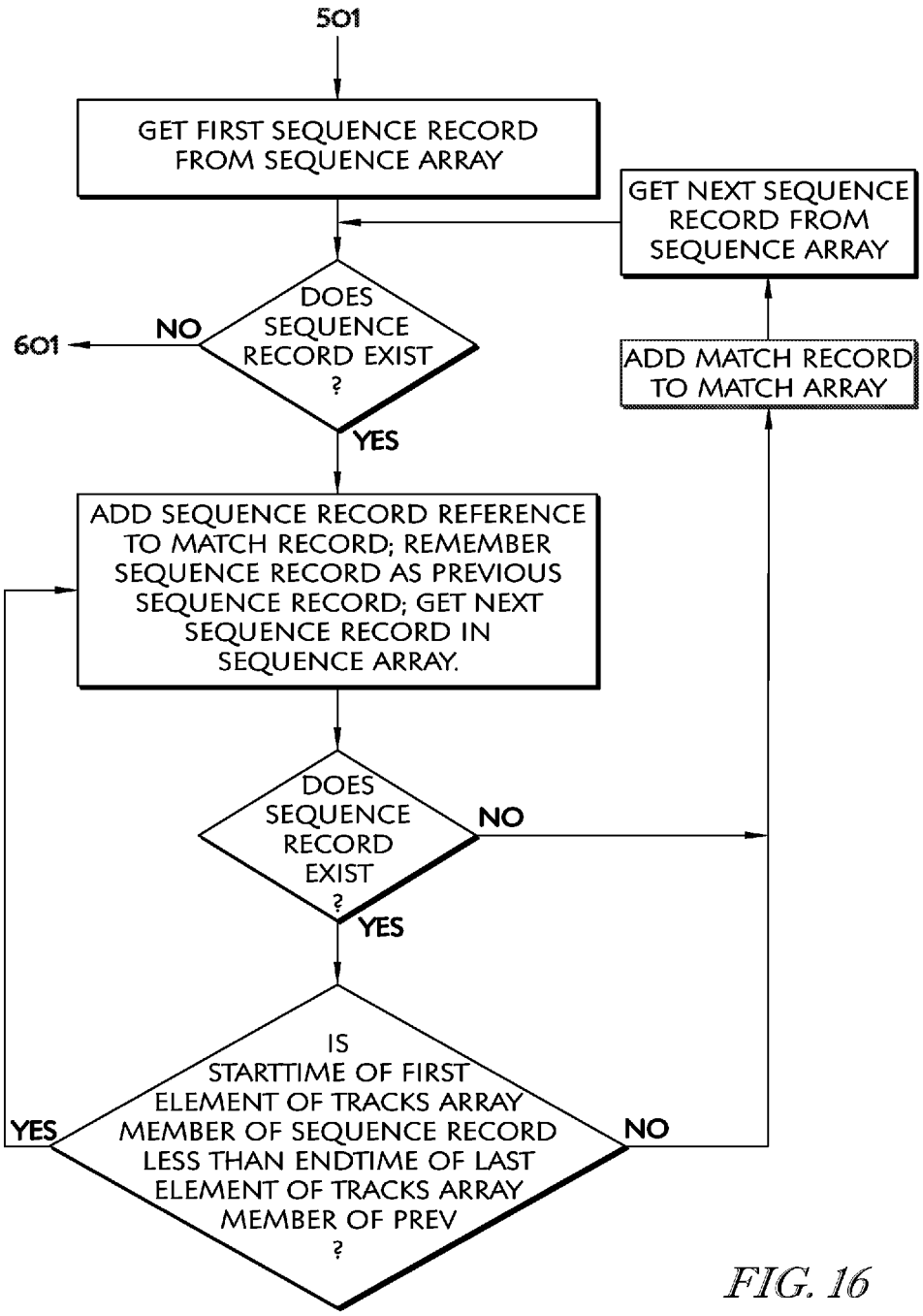
501
GET FIRST SEQUENCE RECORD FROM SEQUENCE ARRAY
GET NEXT SEQUENCE RECORD FROM SEQUENCE ARRAY
DOES SEQUENCE RECORD EXIST ?
NO
601
YES
ADD MATCH RECORD TO MATCH ARRAY
ADD SEQUENCE RECORD REFERENCE TO MATCH RECORD; REMEMBER SEQUENCE RECORD AS PREVIOUS SEQUENCE RECORD; GET NEXT SEQUENCE RECORD IN SEQUENCE ARRAY.
DOES SEQUENCE RECORD EXIST ?
NO
YES
IS STARTTIME OF FIRST ELEMENT OF TRACKS ARRAY MEMBER OF SEQUENCE RECORD LESS THAN ENDTIME OF LAST ELEMENT OF TRACKS ARRAY MEMBER OF PREV ?
YES
NO

FIG. 16

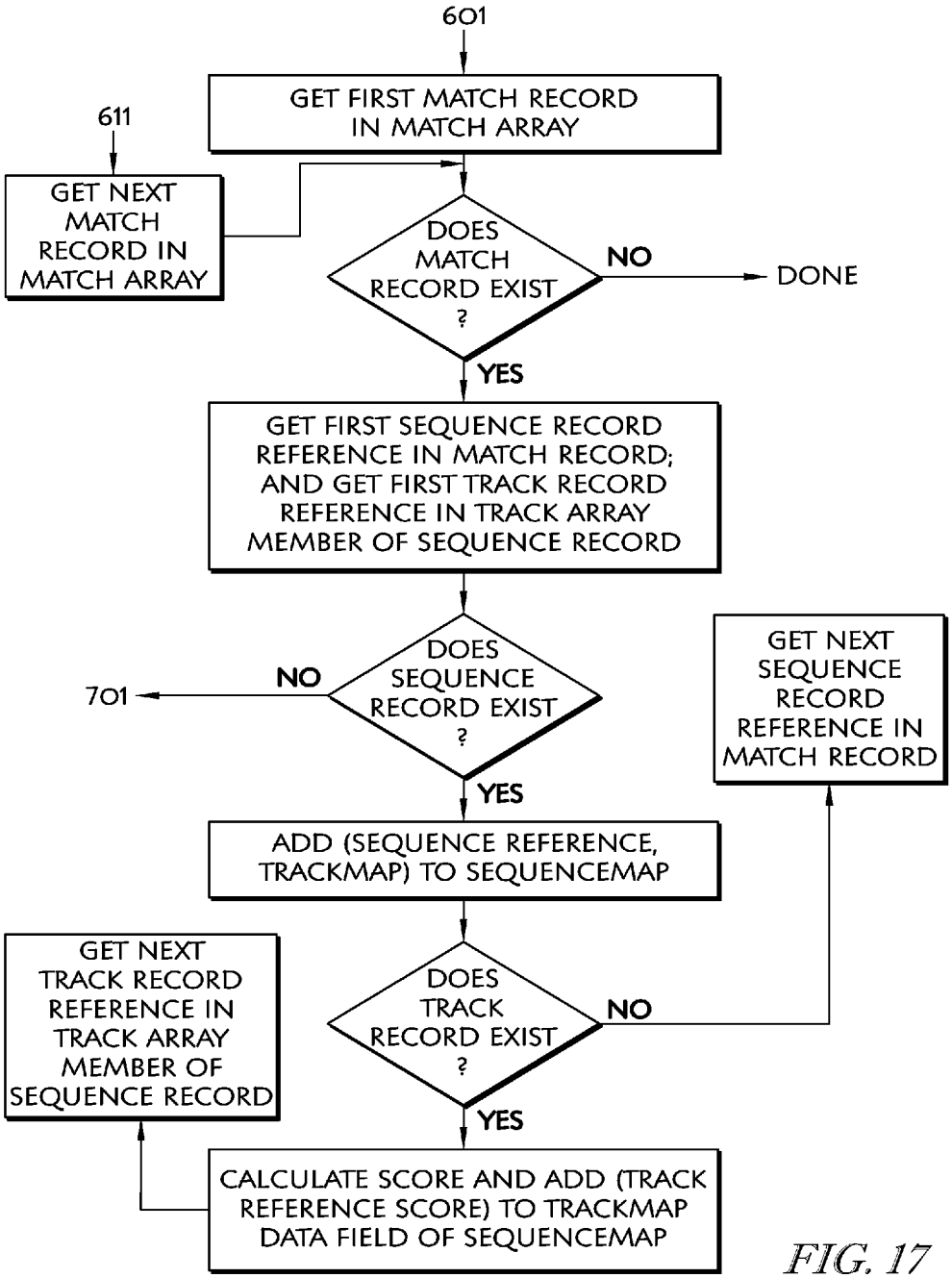
601
GET FIRST MATCH RECORD IN MATCH ARRAY
611
GET NEXT MATCH RECORD IN MATCH ARRAY
DOES MATCH RECORD EXIST ?
NO
DONE
YES
GET FIRST SEQUENCE RECORD REFERENCE IN MATCH RECORD; AND GET FIRST TRACK RECORD REFERENCE IN TRACK ARRAY MEMBER OF SEQUENCE RECORD
DOES SEQUENCE RECORD EXIST ?
NO
701
YES
GET NEXT SEQUENCE RECORD REFERENCE IN MATCH RECORD
ADD (SEQUENCE REFERENCE, TRACKMAP) TO SEQUENCEMAP
GET NEXT TRACK RECORD REFERENCE IN TRACK ARRAY MEMBER OF SEQUENCE RECORD
DOES TRACK RECORD EXIST ?
NO
YES
CALCULATE SCORE AND ADD (TRACK REFERENCE SCORE) TO TRACKMAP DATA FIELD OF SEQUENCEMAP

FIG. 17

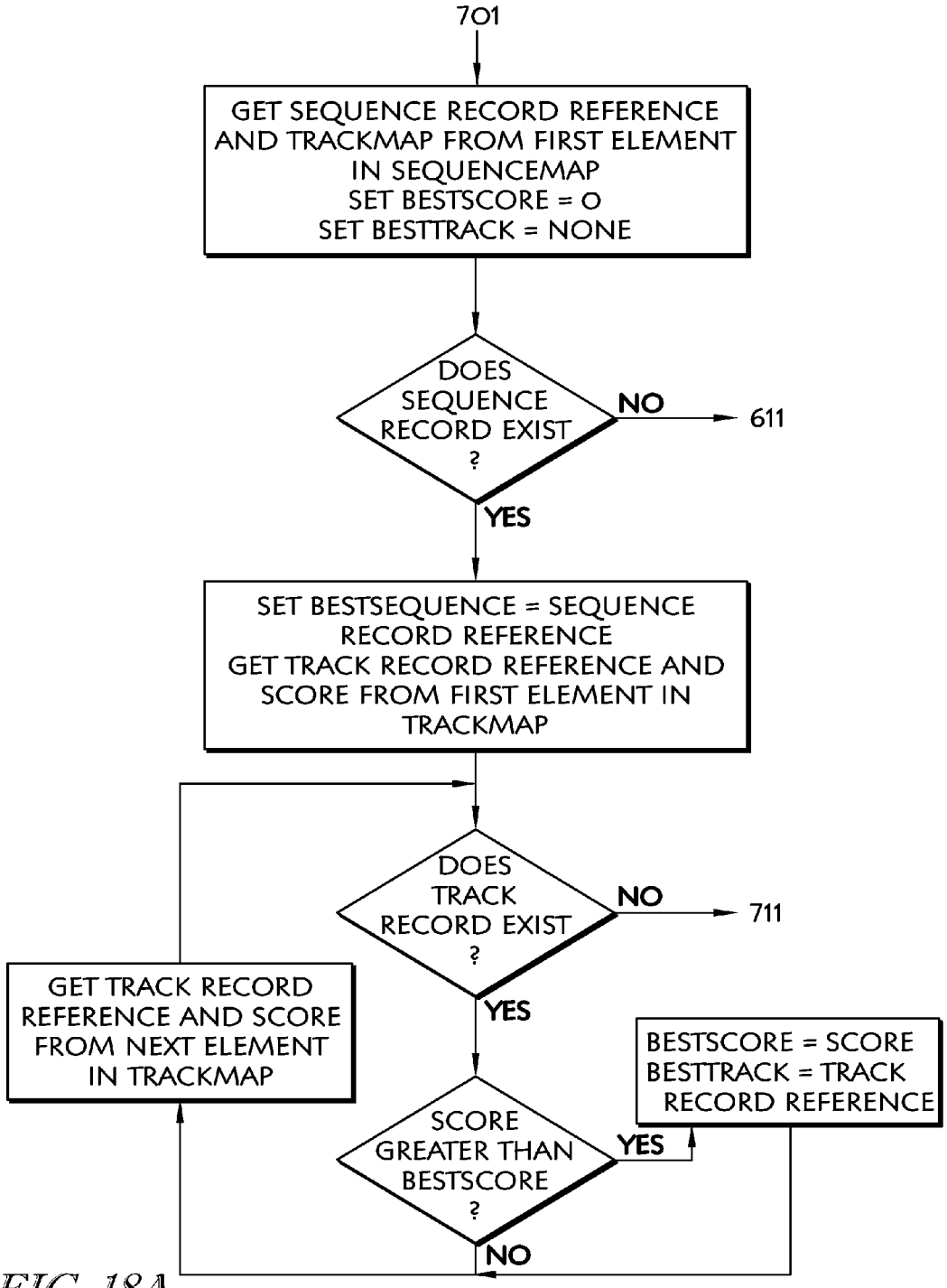
701
GET SEQUENCE RECORD REFERENCE AND TRACKMAP FROM FIRST ELEMENT IN SEQUENCEMAP
SET BESTSCORE = 0
SET BESTTRACK = NONE
DOES SEQUENCE RECORD EXIST ?
NO
611
YES
SET BESTSEQUENCE = SEQUENCE RECORD REFERENCE
GET TRACK RECORD REFERENCE AND SCORE FROM FIRST ELEMENT IN TRACKMAP
DOES TRACK RECORD EXIST ?
NO
711
YES
GET TRACK RECORD REFERENCE AND SCORE FROM NEXT ELEMENT IN TRACKMAP
BESTSCORE = SCORE
BESTTRACK = TRACK RECORD REFERENCE
SCORE GREATER THAN BESTSCORE ?
YES
NO

FIG. 18A

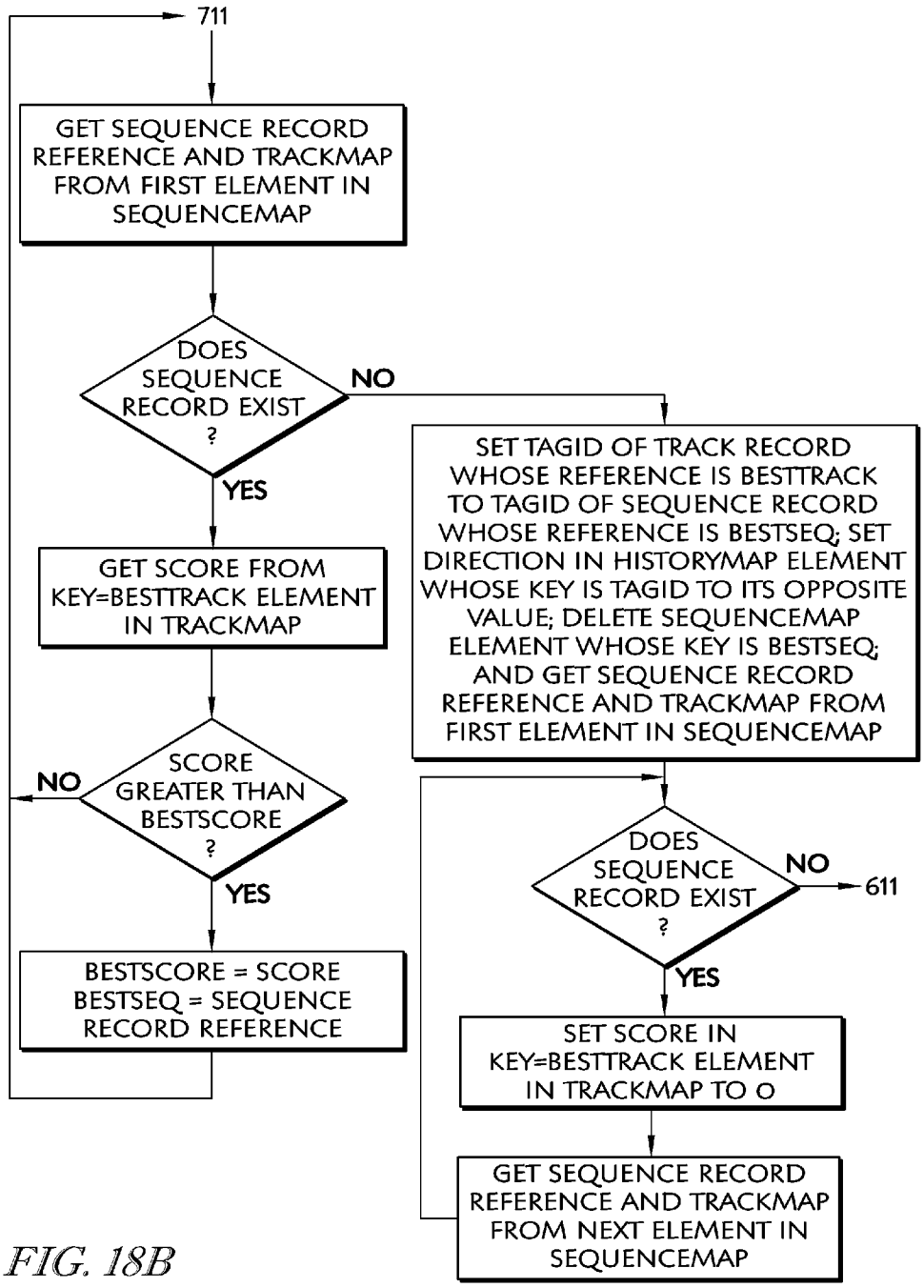
711
GET SEQUENCE RECORD REFERENCE AND TRACKMAP FROM FIRST ELEMENT IN SEQUENCEMAP
DOES SEQUENCE RECORD EXIST ?
NO
YES
GET SCORE FROM KEY=BESTTRACK ELEMENT IN TRACKMAP
SCORE GREATER THAN BESTSCORE ?
NO
YES
BESTSCORE = SCORE
BESTSEQ = SEQUENCE RECORD REFERENCE
SET TAGID OF TRACK RECORD WHOSE REFERENCE IS BESTTRACK TO TAGID OF SEQUENCE RECORD WHOSE REFERENCE IS BESTSEQ; SET DIRECTION IN HISTORYMAP ELEMENT WHOSE KEY IS TAGID TO ITS OPPOSITE VALUE; DELETE SEQUENCEMAP ELEMENT WHOSE KEY IS BESTSEQ; AND GET SEQUENCE RECORD REFERENCE AND TRACKMAP FROM FIRST ELEMENT IN SEQUENCEMAP
DOES SEQUENCE RECORD EXIST ?
NO
611
YES
SET SCORE IN KEY=BESTTRACK ELEMENT IN TRACKMAP TO 0
GET SEQUENCE RECORD REFERENCE AND TRACKMAP FROM NEXT ELEMENT IN SEQUENCEMAP

FIG. 18B

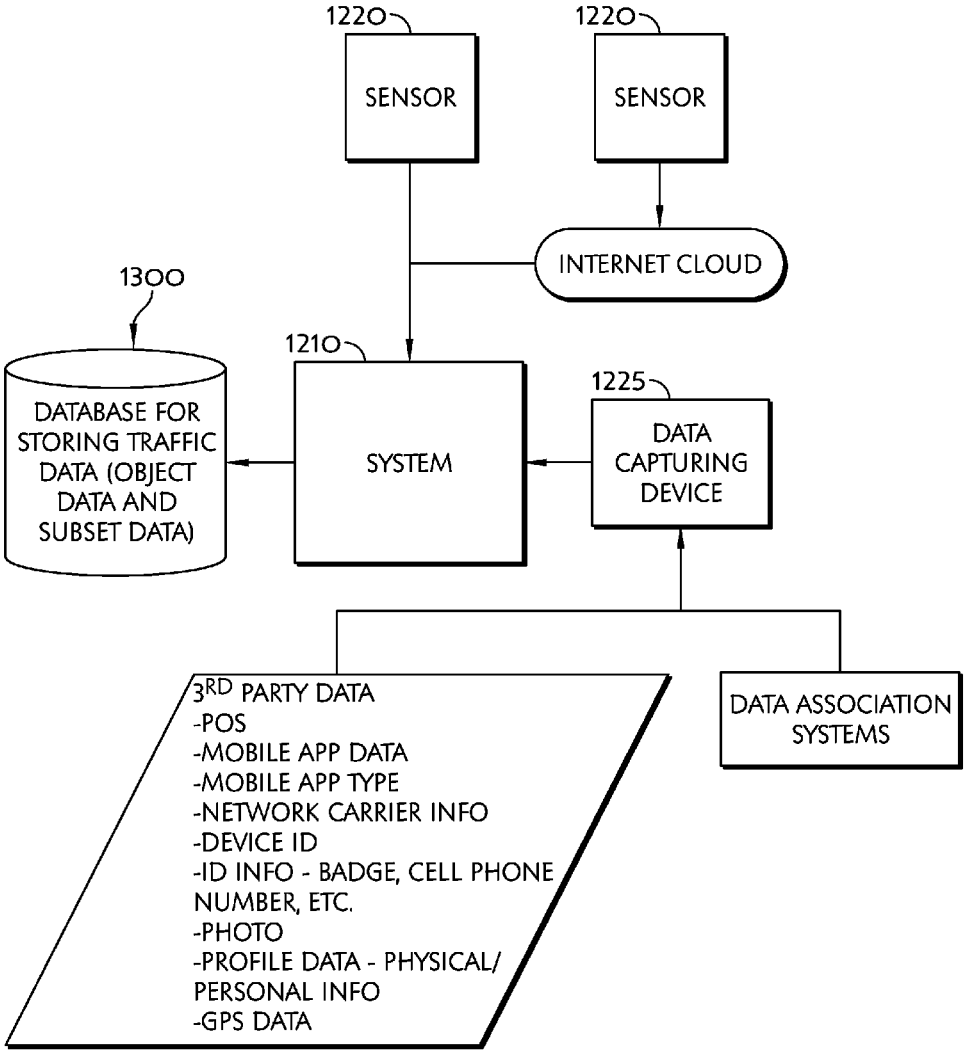
1220
SENSOR
1220
SENSOR
INTERNET CLOUD
1300
DATABASE FOR STORING TRAFFIC DATA (OBJECT DATA AND SUBSET DATA)
1210
SYSTEM
1225
DATA CAPTURING DEVICE
3RD PARTY DATA
-POS
-MOBILE APP DATA
-MOBILE APP TYPE
-NETWORK CARRIER INFO
-DEVICE ID
-ID INFO - BADGE, CELL PHONE NUMBER, ETC.
-PHOTO
-PROFILE DATA - PHYSICAL/ PERSONAL INFO
-GPS DATA
DATA ASSOCIATION SYSTEMS

FIG. 19

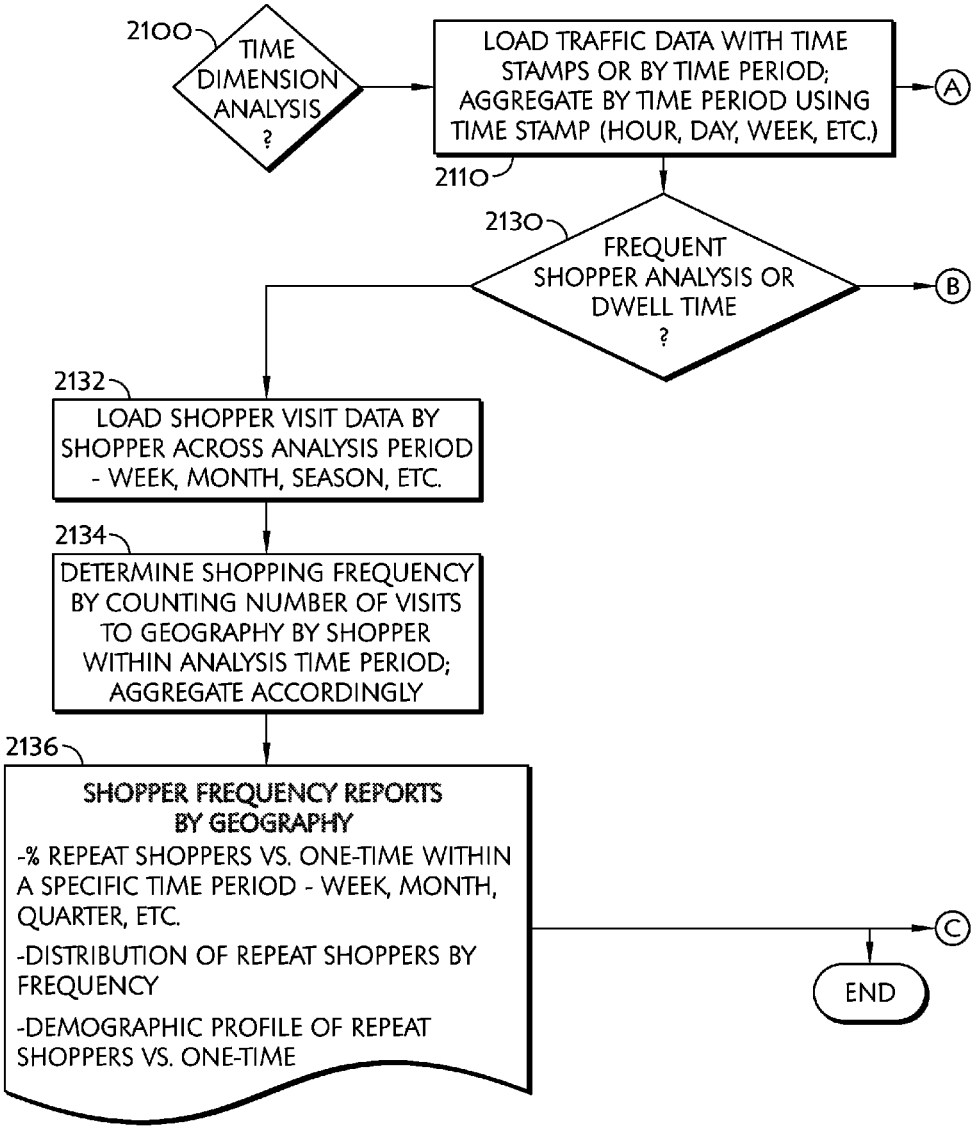
2100
TIME DIMENSION ANALYSIS ?
LOAD TRAFFIC DATA WITH TIME STAMPS OR BY TIME PERIOD; AGGREGATE BY TIME PERIOD USING TIME STAMP (HOUR, DAY, WEEK, ETC.)
A
2110
2130
FREQUENT SHOPPER ANALYSIS OR DWELL TIME ?
B
2132
LOAD SHOPPER VISIT DATA BY SHOPPER ACROSS ANALYSIS PERIOD - WEEK, MONTH, SEASON, ETC.
2134
DETERMINE SHOPPING FREQUENCY BY COUNTING NUMBER OF VISITS TO GEOGRAPHY BY SHOPPER WITHIN ANALYSIS TIME PERIOD; AGGREGATE ACCORDINGLY
2136
SHOPPER FREQUENCY REPORTS BY GEOGRAPHY
-% REPEAT SHOPPERS VS. ONE-TIME WITHIN A SPECIFIC TIME PERIOD - WEEK, MONTH, QUARTER, ETC.
-DISTRIBUTION OF REPEAT SHOPPERS BY FREQUENCY
-DEMOGRAPHIC PROFILE OF REPEAT SHOPPERS VS. ONE-TIME
C
END

FIG. 20A

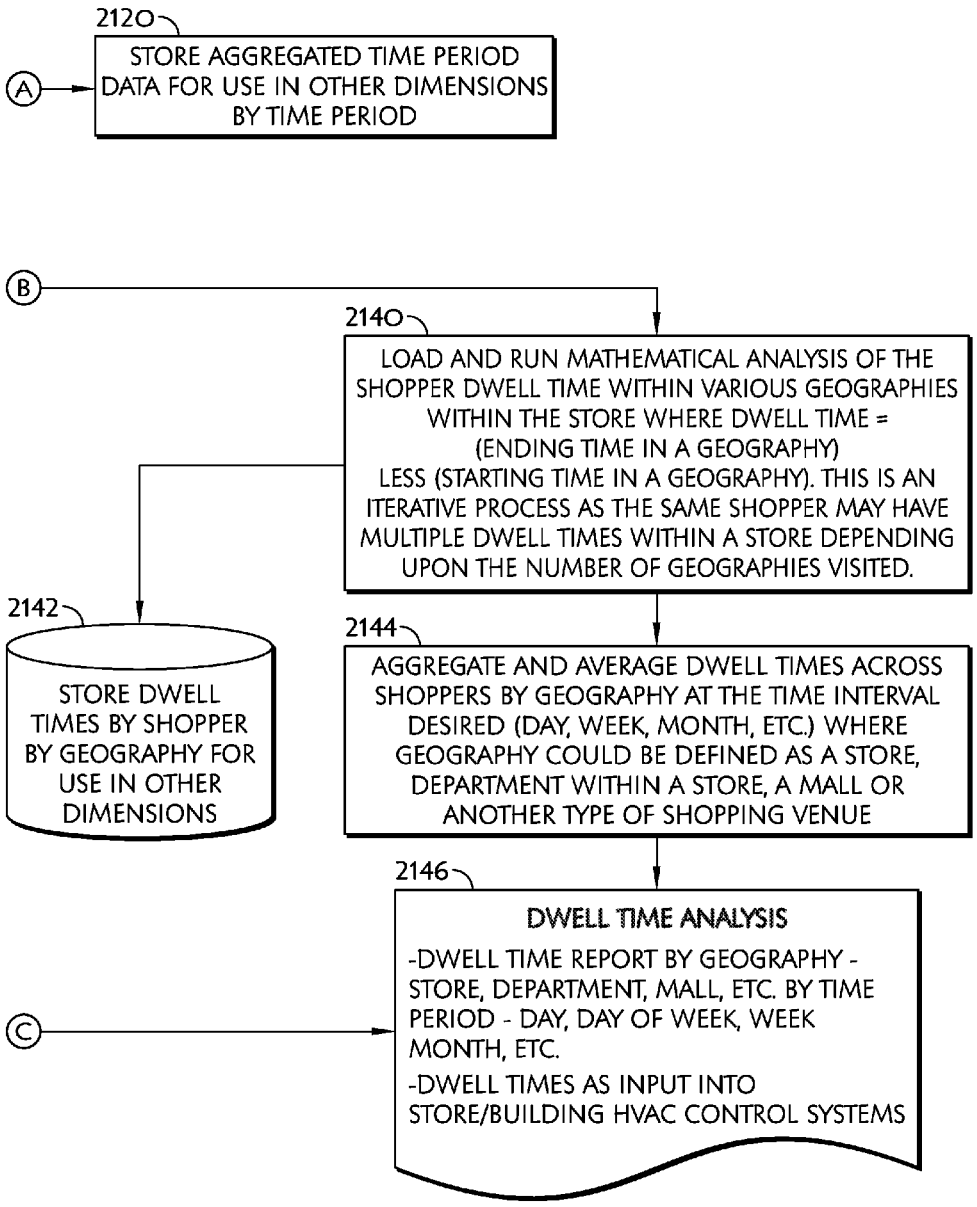
2120
STORE AGGREGATED TIME PERIOD DATA FOR USE IN OTHER DIMENSIONS BY TIME PERIOD
A
B
2140
LOAD AND RUN MATHEMATICAL ANALYSIS OF THE SHOPPER DWELL TIME WITHIN VARIOUS GEOGRAPHIES WITHIN THE STORE WHERE DWELL TIME = (ENDING TIME IN A GEOGRAPHY) LESS (STARTING TIME IN A GEOGRAPHY). THIS IS AN ITERATIVE PROCESS AS THE SAME SHOPPER MAY HAVE MULTIPLE DWELL TIMES WITHIN A STORE DEPENDING UPON THE NUMBER OF GEOGRAPHIES VISITED.
2142
STORE DWELL TIMES BY SHOPPER BY GEOGRAPHY FOR USE IN OTHER DIMENSIONS
2144
AGGREGATE AND AVERAGE DWELL TIMES ACROSS SHOPPERS BY GEOGRAPHY AT THE TIME INTERVAL DESIRED (DAY, WEEK, MONTH, ETC.) WHERE GEOGRAPHY COULD BE DEFINED AS A STORE, DEPARTMENT WITHIN A STORE, A MALL OR ANOTHER TYPE OF SHOPPING VENUE
2146
DWELL TIME ANALYSIS
-DWELL TIME REPORT BY GEOGRAPHY - STORE, DEPARTMENT, MALL, ETC. BY TIME PERIOD - DAY, DAY OF WEEK, WEEK MONTH, ETC.
-DWELL TIMES AS INPUT INTO STORE/BUILDING HVAC CONTROL SYSTEMS
C

FIG. 20B

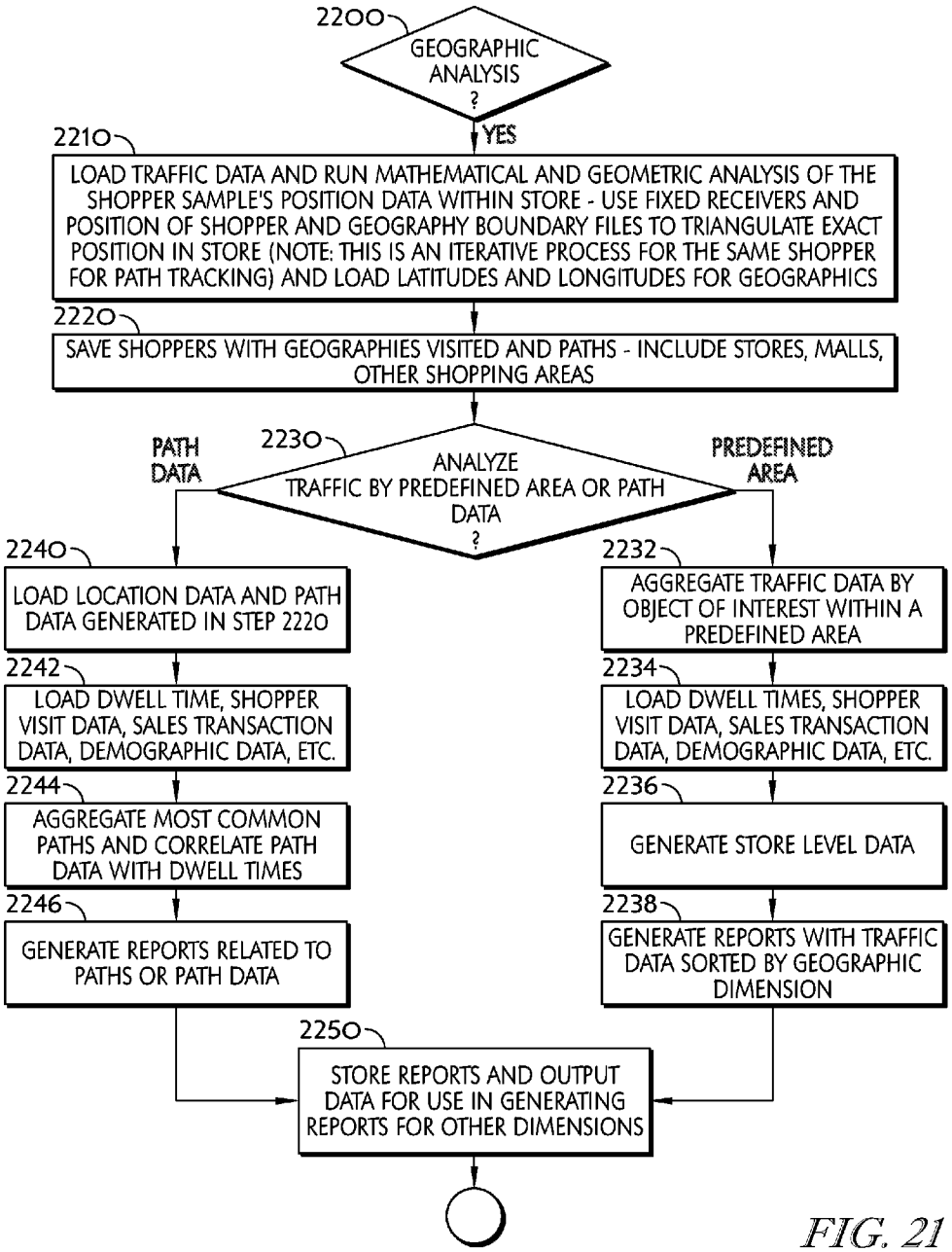
2200
GEOGRAPHIC ANALYSIS ?
YES
2210
LOAD TRAFFIC DATA AND RUN MATHEMATICAL AND GEOMETRIC ANALYSIS OF THE SHOPPER SAMPLE'S POSITION DATA WITHIN STORE - USE FIXED RECEIVERS AND POSITION OF SHOPPER AND GEOGRAPHY BOUNDARY FILES TO TRIANGULATE EXACT POSITION IN STORE (NOTE: THIS IS AN ITERATIVE PROCESS FOR THE SAME SHOPPER FOR PATH TRACKING) AND LOAD LATITUDES AND LONGITUDES FOR GEOGRAPHICS
2220
SAVE SHOPPERS WITH GEOGRAPHIES VISITED AND PATHS - INCLUDE STORES, MALLS, OTHER SHOPPING AREAS
2230
ANALYZE TRAFFIC BY PREDEFINED AREA OR PATH DATA ?
PATH DATA
PREDEFINED AREA
2240
LOAD LOCATION DATA AND PATH DATA GENERATED IN STEP 2220
2242
LOAD DWELL TIME, SHOPPER VISIT DATA, SALES TRANSACTION DATA, DEMOGRAPHIC DATA, ETC.
2244
AGGREGATE MOST COMMON PATHS AND CORRELATE PATH DATA WITH DWELL TIMES
2246
GENERATE REPORTS RELATED TO PATHS OR PATH DATA
2232
AGGREGATE TRAFFIC DATA BY OBJECT OF INTEREST WITHIN A PREDEFINED AREA
2234
LOAD DWELL TIMES, SHOPPER VISIT DATA, SALES TRANSACTION DATA, DEMOGRAPHIC DATA, ETC.
2236
GENERATE STORE LEVEL DATA
2238
GENERATE REPORTS WITH TRAFFIC DATA SORTED BY GEOGRAPHIC DIMENSION
2250
STORE REPORTS AND OUTPUT DATA FOR USE IN GENERATING REPORTS FOR OTHER DIMENSIONS

FIG. 21

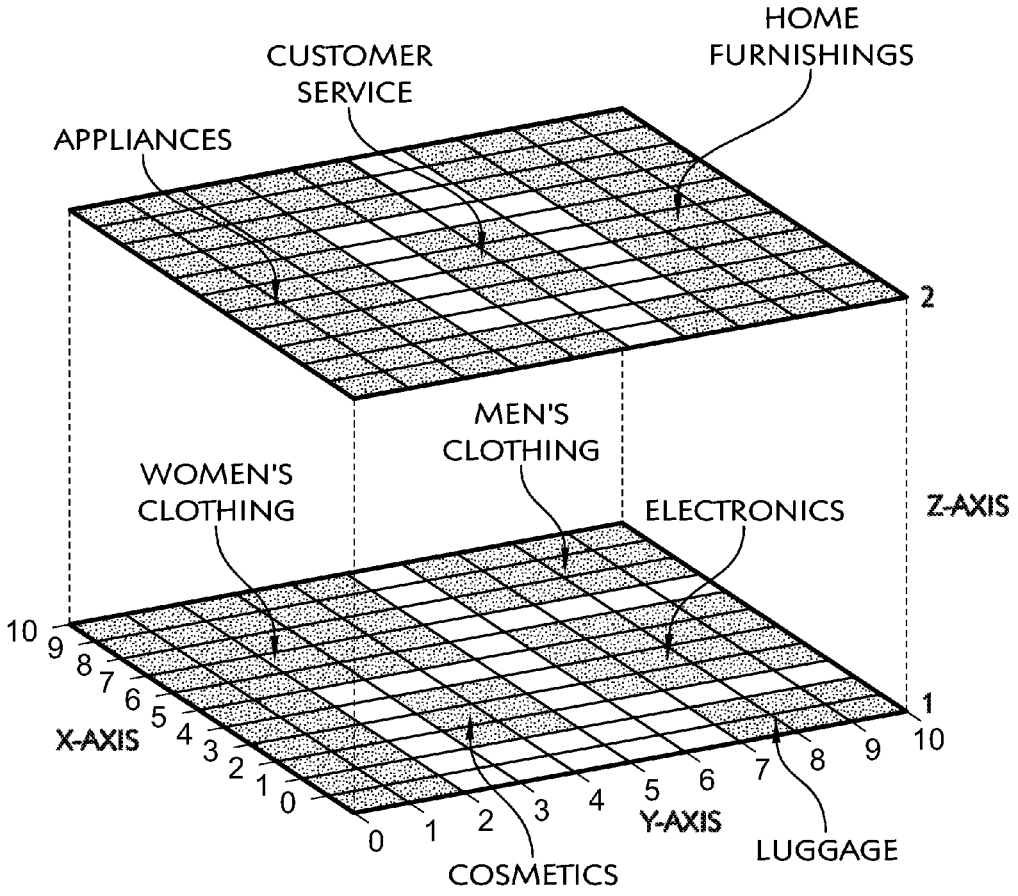
HOME
FURNISHINGS
CUSTOMER
SERVICE
APPLIANCES
2
MEN'S
CLOTHING
WOMEN'S
CLOTHING
ELECTRONICS
Z-AXIS
10
9
8
7
6
5
4
3
2
1
0
X-AXIS
1
10
0
1
2
3
4
5
6
7
8
9
Y-AXIS
COSMETICS
LUGGAGE

FIG. 22

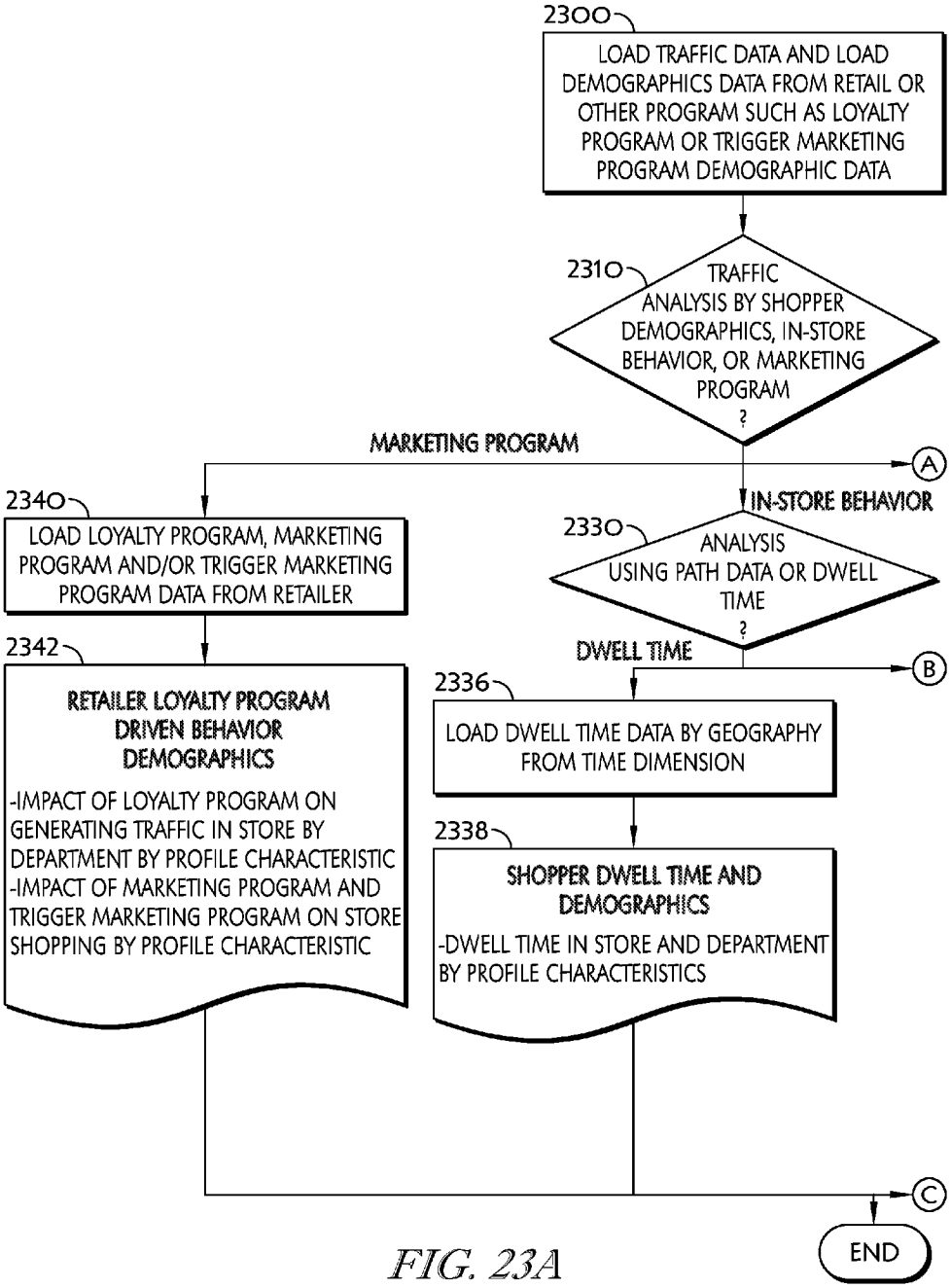
2300
LOAD TRAFFIC DATA AND LOAD DEMOGRAPHICS DATA FROM RETAIL OR OTHER PROGRAM SUCH AS LOYALTY PROGRAM OR TRIGGER MARKETING PROGRAM DEMOGRAPHIC DATA
2310
TRAFFIC ANALYSIS BY SHOPPER DEMOGRAPHICS, IN-STORE BEHAVIOR, OR MARKETING PROGRAM ?
MARKETING PROGRAM
A
IN-STORE BEHAVIOR
2340
LOAD LOYALTY PROGRAM, MARKETING PROGRAM AND/OR TRIGGER MARKETING PROGRAM DATA FROM RETAILER
2330
ANALYSIS USING PATH DATA OR DWELL TIME ?
DWELL TIME
B
2342
RETAILER LOYALTY PROGRAM DRIVEN BEHAVIOR DEMOGRAPHICS
-IMPACT OF LOYALTY PROGRAM ON GENERATING TRAFFIC IN STORE BY DEPARTMENT BY PROFILE CHARACTERISTIC
-IMPACT OF MARKETING PROGRAM AND TRIGGER MARKETING PROGRAM ON STORE SHOPPING BY PROFILE CHARACTERISTIC
2336
LOAD DWELL TIME DATA BY GEOGRAPHY FROM TIME DIMENSION
2338
SHOPPER DWELL TIME AND DEMOGRAPHICS
-DWELL TIME IN STORE AND DEPARTMENT BY PROFILE CHARACTERISTICS
C
END

FIG. 23A

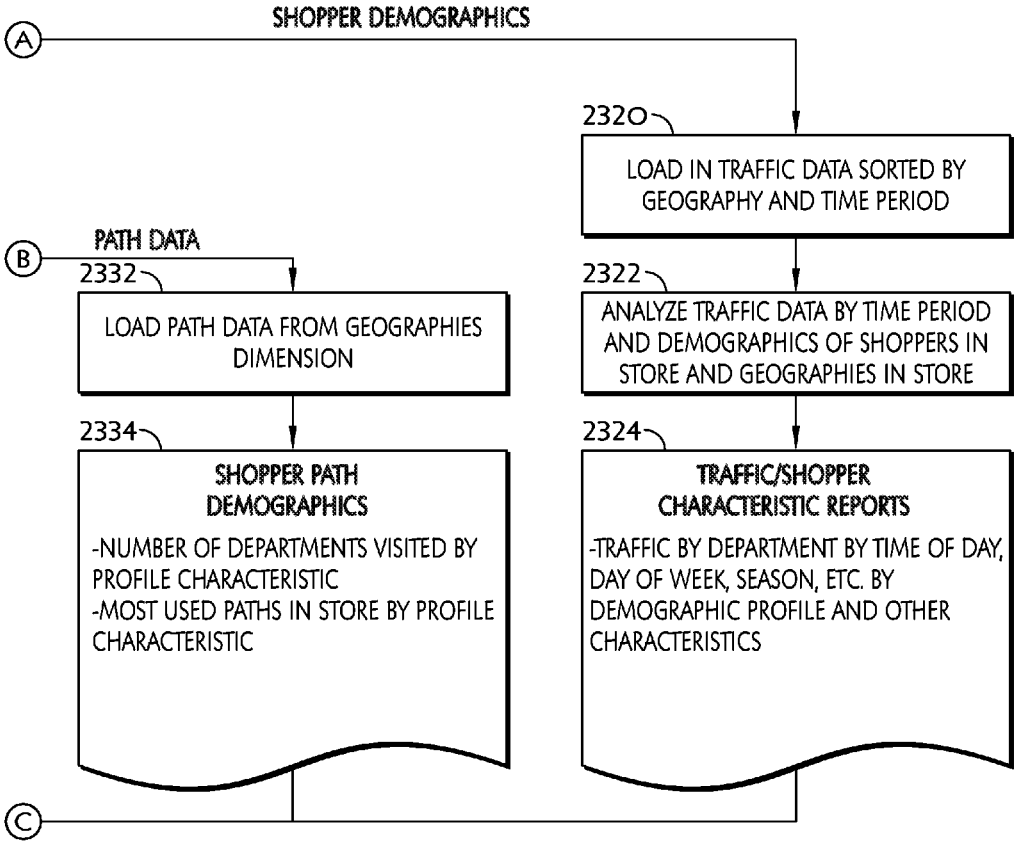
SHOPPER DEMOGRAPHICS
A
2320
LOAD IN TRAFFIC DATA SORTED BY GEOGRAPHY AND TIME PERIOD
PATH DATA
B
2332
LOAD PATH DATA FROM GEOGRAPHIES DIMENSION
2322
ANALYZE TRAFFIC DATA BY TIME PERIOD AND DEMOGRAPHICS OF SHOPPERS IN STORE AND GEOGRAPHIES IN STORE
2334
SHOPPER PATH DEMOGRAPHICS
-NUMBER OF DEPARTMENTS VISITED BY PROFILE CHARACTERISTIC
-MOST USED PATHS IN STORE BY PROFILE CHARACTERISTIC
2324
TRAFFIC/SHOPPER CHARACTERISTIC REPORTS
-TRAFFIC BY DEPARTMENT BY TIME OF DAY, DAY OF WEEK, SEASON, ETC. BY DEMOGRAPHIC PROFILE AND OTHER CHARACTERISTICS
C

FIG. 23B

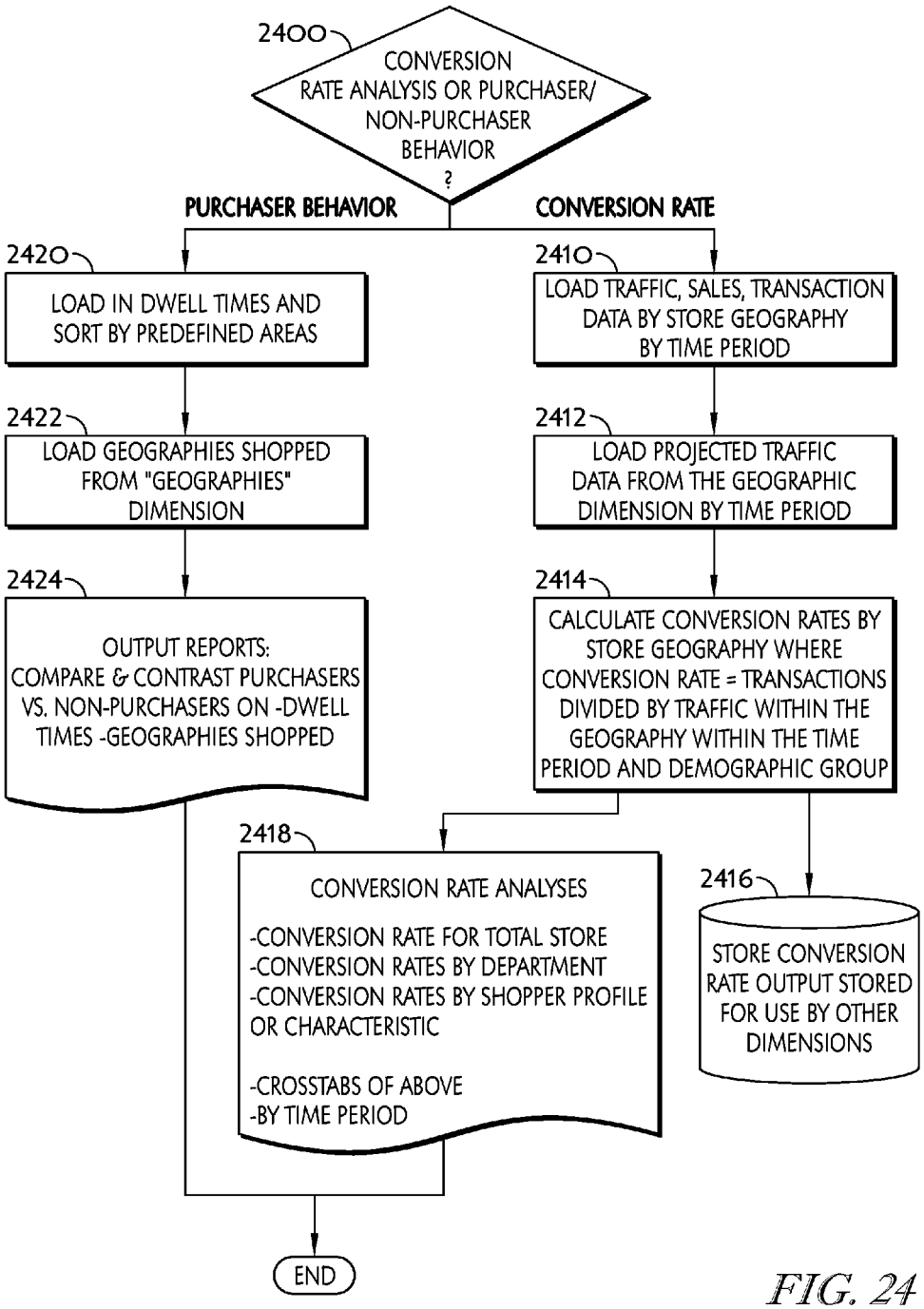
2400
CONVERSION RATE ANALYSIS OR PURCHASER/ NON-PURCHASER BEHAVIOR ?
PURCHASER BEHAVIOR
CONVERSION RATE
2420
LOAD IN DWELL TIMES AND SORT BY PREDEFINED AREAS
2410
LOAD TRAFFIC, SALES, TRANSACTION DATA BY STORE GEOGRAPHY BY TIME PERIOD
2422
LOAD GEOGRAPHIES SHOPPED FROM "GEOGRAPHIES" DIMENSION
2412
LOAD PROJECTED TRAFFIC DATA FROM THE GEOGRAPHIC DIMENSION BY TIME PERIOD
2424
OUTPUT REPORTS: COMPARE & CONTRAST PURCHASERS VS. NON-PURCHASERS ON -DWELL TIMES -GEOGRAPHIES SHOPPED
2414
CALCULATE CONVERSION RATES BY STORE GEOGRAPHY WHERE CONVERSION RATE = TRANSACTIONS DIVIDED BY TRAFFIC WITHIN THE GEOGRAPHY WITHIN THE TIME PERIOD AND DEMOGRAPHIC GROUP
2418
CONVERSION RATE ANALYSES
-CONVERSION RATE FOR TOTAL STORE
-CONVERSION RATES BY DEPARTMENT
-CONVERSION RATES BY SHOPPER PROFILE OR CHARACTERISTIC
-CROSSTABS OF ABOVE
-BY TIME PERIOD
2416
STORE CONVERSION RATE OUTPUT STORED FOR USE BY OTHER DIMENSIONS
END

FIG. 24

SYSTEM AND METHOD FOR DETECTING, TRACKING AND COUNTING HUMAN OBJECTS OF INTEREST USING A COUNTING SYSTEM AND A DATA CAPTURE DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of copending patent application Ser. No. 13/622,083, filed Sep. 18, 2012, which claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Patent Application No. 61/538,554, filed on Sep. 23, 2011, and U.S. Provisional Patent Application No. 61/549,511, filed on Oct. 20, 2011. The disclosures set forth in the referenced applications are incorporated herein by reference in their entireties.

BACKGROUND

1. Field of the Invention

The present invention generally relates to the field of object detection, tracking, and counting. In specific, the present invention is a computer-implemented detection and tracking system and process for detecting and tracking human objects of interest that appear in camera images taken, for example, at an entrance or entrances to a facility, as well as counting the number of human objects of interest entering or exiting the facility for a given time period.

2. Related Prior Art

Traditionally, various methods for detecting and counting the passing of an object have been proposed. U.S. Pat. No. 7,161,482 describes an integrated electronic article surveillance (EAS) and people counting system. The EAS component establishes an interrogatory zone by an antenna positioned adjacent to the interrogation zone at an exit point of a protected area. The people counting component includes one people detection device to detect the passage of people through an associated passageway and provide a people detection signal, and another people detection device placed at a predefined distance from the first device and configured to detect another people detection signal. The two signals are then processed into an output representative of a direction of travel in response to the signals.

Basically, there are two classes of systems employing video images for locating and tracking human objects of interest. One class uses monocular video streams or image sequences to extract, recognize, and track objects of interest. The other class makes use of two or more video sensors to derive range or height maps from multiple intensity images and uses the range or height maps as a major data source.

In monocular systems, objects of interest are detected and tracked by applying background differencing, or by adaptive template matching, or by contour tracking. The major problem with approaches using background differencing is the presence of background clutters, which negatively affect robustness and reliability of the system performance. Another problem is that the background updating rate is hard to adjust in real applications. The problems with approaches using adaptive template matching are:

1) object detections tend to drift from true locations of the objects, or get fixed to strong features in the background; and

2) the detections are prone to occlusion. Approaches using the contour tracking suffer from difficulty in overcoming degradation by intensity gradients in the background near contours of the objects. In addition, all the previously mentioned methods are susceptible to changes in lighting conditions, shadows, and sunlight.

In stereo or multi-sensor systems, intensity images taken by sensors are converted to range or height maps, and the conversion is not affected by adverse factors such as lighting condition changes, strong shadow, or sunlight.

Therefore, performances of stereo systems are still very robust and reliable in the presence of adverse factors such as hostile lighting conditions. In addition, it is easier to use range or height information for segmenting, detecting, and tracking objects than to use intensity information.

Most state-of-the-art stereo systems use range background differencing to detect objects of interest. Range background differencing suffers from the same problems such as background clutter, as the monocular background differencing approaches, and presents difficulty in differentiating between multiple closely positioned objects.

U.S. Pat. No. 6,771,818 describes a system and process of identifying and locating people and objects of interest in a scene by selectively clustering blobs to generate "candidate blob clusters" within the scene and comparing the blob clusters to a model representing the people or objects of interest. The comparison of candidate blob clusters to the model identifies the blob clusters that is the closest match or matches to the model. Sequential live depth images may be captured and analyzed in real-time to provide for continuous identification and location of people or objects as a function of time.

U.S. Pat. Nos. 6,952,496 and 7,092,566 are directed to a system and process employing color images, color histograms, techniques for compensating variations, and a sum of match qualities approach to best identify each of a group of people and objects in the image of a scene. An image is segmented to extract regions which likely correspond to people and objects of interest and a histogram is computed for each of the extracted regions. The histogram is compared with pre-computed model histograms and is designated as corresponding to a person or object if the degree of similarity exceeds a prescribed threshold. The designated histogram can also be stored as an additional model histogram.

U.S. Pat. No. 7,176,441 describes a counting system for counting the number of persons passing a monitor line set in the width direction of a path. A laser is installed for irradiating the monitor line with a slit ray and an image capturing device is deployed for photographing an area including the monitor line. The number of passing persons is counted on the basis of one dimensional data generated from an image obtained from the photographing when the slit ray is interrupted on the monitor line when a person passes the monitor line.

Despite all the prior art in this field, no invention has developed a technology that enables unobtrusive detection and tracking of moving human objects, requiring low budget and maintenance while providing precise traffic counting results with the ability to distinguish between incoming and outgoing traffic, moving and static objects, and between objects of different heights. Thus, it is a primary objective of this invention to provide an unobtrusive traffic detection, tracking, and counting system that involves low cost, easy and low maintenance, high-speed processing, and capable of providing time-stamped results that can be further analyzed.

In addition, people counting systems typically create anonymous traffic counts. In retail traffic monitoring, however, this may be insufficient. For example, some situations may require store employees to accompany customers through access points that are being monitored by an object tracking and counting system, such as fitting rooms. In these

circumstances, existing systems are unable to separately track and count employees and customers. The present invention would solve this deficiency.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, a method for counting and tracking defined objects comprises the step of receiving subset data with a data capturing device, wherein the subset data is associated with defined objects and includes a unique identifier, an entry time, an exit time, and location data for each defined object. The method may further include the steps of receiving subset data at a counting system, counting the defined objects, tracking the defined objects, associating a location of a defined object with a predefined area, and/or generating path data by plotting X and Y coordinates for the defined object within the predefined area at sequential time periods

In some embodiments, the method may further include the step of receiving location data at the data capturing device, wherein the location data is received from tracking technology that detects cellular signals emitted from one or more mobile handsets or signals emitted from membership cards, employee badges, rail or air tickets, rental car keys, hotel keys, store-sponsored credit or debit cards, or loyalty reward cards with RFID chips.

In some embodiments, the cellular signals include T-IMSI, CDMA, or Wi-Fi signals.

In some embodiments, the method may further include the step of receiving data from another independent system regarding physical characteristics of the object.

In some embodiments, the other independent system may be selected from the group consisting of point of sale systems, loyalty rewards systems, point of sale trigger information, and mechanical turks.

In some embodiments, the method may further include the steps of converting the subset data into sequence records and creating a sequence array of all of the sequence records, wherein a sequence record may include: (a) a unique ID, which is an unsigned integer associated with a mobile handset, a telephone number associated with the mobile handset or any other unique number, character, or combination thereof, associated with object, (b) a start time, which may consist of information indicative of a time when the object was first detected within a coverage area, (c) an end time, which may consist of information indicative of a time when the object was last detected within the coverage area of the data capturing device, and/or (d) an array of references to all tracks that overlap a particular sequence record.

In some embodiments, the method may further include the step of determining a dwell time for an object within a predefined area by subtracting the end time for that predetermined area from the start time for that predetermined area.

In some embodiments, the method may further include the step of using Z coordinates to further track objects within a predefined area defined by multiple floors.

In some embodiments, the method may further include the step of using the subset data to generate reports showing at least one of the number of objects within a predefined area, a number of objects within the predefined area during a specific time period, a number of predefined areas that were visited by an object, or dwell times for one or more predefined areas.

In some embodiments, the method may further include the step of using at least path data and subset data to aggregate the most common paths taken by objects and correlate path data information with dwell times.

In some embodiments, the method may further include the step of generating a report that shows at least one of the following: (a) the most common paths that objects take in a store, including corresponding dwell times, (b) changes in shopping patterns by time period or season, and/or (c) traffic patterns for use by store security or HVAC systems in increasing or decreasing resources at particular times.

In some embodiments, the method may further include the step of generating a conversion rate by (a) loading transaction data related to transactions performed, (b) loading traffic data including a traffic count and sorting by time periods, and/or (c) dividing the transactions by the traffic counts for the time periods.

In some embodiments, the transaction data may include a sales amount, the number of items purchases, the specific items purchased, the data and time of the transaction, the register used for the transaction, and the sales associate that completed the transaction.

In some embodiments, the method may further include the step of generating a report showing comparisons between purchasers and non-purchasers based on at least one of the dwell times, the predefined areas, or the time periods.

In accordance with these and other objectives that will become apparent hereafter, the present invention will be described with particular references to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic perspective view of a facility in which the system of the present invention is installed;

FIG. **2** is a diagram illustrating the image capturing device connected to an exemplary counting system of the present invention;

FIG. **3** is a diagram illustrating the sequence of converting one or more stereo image pairs captured by the system of the present invention into the height maps, which are analyzed to track and count human objects;

FIG. **4** is a flow diagram describing the flow of processes for a system performing human object detection, tracking, and counting according to the present invention;

FIG. **5** is a flow diagram describing the flow of processes for object tracking;

FIGS. **6**A-B are a flow diagram describing the flow of processes for track analysis;

FIGS. **7**A-B are a first part of a flow diagram describing the flow of processes for suboptimal localization of unpaired tracks;

FIGS. **8**A-B are a second part of the flow diagram of FIG. **7** describing the flow of processes for suboptimal localization of unpaired tracks;

FIGS. **9**A-B are is a flow diagram describing the flow of processes for second pass matching of tracks and object detects;

FIG. **10** is a flow diagram describing the flow of processes for track updating or creation;

FIG. **11** is a flow diagram describing the flow of processes for track merging;

FIG. **12** is a flow diagram describing the flow of processes for track updates;

FIG. **13** is a diagram illustrating the image capturing device connected to an exemplary counting system, which includes an RFID reader;

FIG. **14** is a flow diagram depicting the flow of processes for retrieving object data and tag data and generating track arrays and sequence arrays;

FIG. **15** is a flow diagram depicting the flow of processes for determining whether any overlap exists between any of the track records and any of the sequence records;

FIG. **16** is a flow diagram depicting the flow of processes for generating a match record **316** for each group of sequence records whose track records overlap;

FIG. **17** is a flow diagram depicting the flow of processes for calculating the match quality scores;

FIG. **18**A is a flow diagram depicting the flow of processes for determining which track record is the best match for a particular sequence;

FIG. **18**B is a flow diagram depicting the flow of processes for determining the sequence record that holds the sequence record/track record combination with the highest match quality score;

FIG. **19** is a diagram illustrating an image capturing device connected to an exemplary counting system, which also includes a data capturing device;

FIGS. **20**A-B are a flow diagram depicting the steps for generating reports based on a time dimension;

FIG. **21** is a flow diagram depicting the steps for generating reports based on a geographic dimension;

FIG. **22** is a diagram illustrating a multi-floor area;

FIGS. **23**A-B are is a flow diagram depicting the steps for generating reports based on a behavioral dimension; and

FIG. **24** is a flow diagram depicting the steps for generating reports based on a demographic dimension.

DETAILED DESCRIPTION OF THE INVENTION

This detailed description is presented in terms of programs, data structures or procedures executed on a computer or a network of computers. The software programs implemented by the system may be written in languages such as JAVA, C, C++, C#, Assembly language, Python, PHP, or HTML. However, one of skill in the art will appreciate that other languages may be used instead, or in combination with the foregoing.

1. System Components

Referring to FIGS. **1**, **2** and **3**, the present invention is a system **10** comprising at least one image capturing device **20** electronically or wirelessly connected to a counting system **30**. In the illustrated embodiment, the at least one image capturing device **20** is mounted above an entrance or entrances **21** to a facility **23** for capturing images from the entrance or entrances **21**. Facilities such as malls or stores with wide entrances often require more than one image capturing device to completely cover the entrances. The area captured by the image capturing device **20** is field of view **44**. Each image, along with the time when the image is captured, is a frame **48** (FIG. **3**).

Typically, the image capturing device includes at least one stereo camera with two or more video sensors **46** (FIG. **2**), which allows the camera to simulate human binocular vision. A pair of stereo images comprises frames **48** taken by each video sensor **46** of the camera. A height map **56** is then constructed from the pair of stereo images through computations involving finding corresponding pixels in rectified frames **52**, **53** of the stereo image pair.

Door zone **84** is an area in the height map **56** marking the start position of an incoming track and end position of an outgoing track. Interior zone **86** is an area marking the end position of the incoming track and the start position of the outgoing track. Dead zone **90** is an area in the field of view **44** that is not processed by the counting system **30**.

Video sensors **46** (FIG. **2**) receive photons through lenses, and photons cause electrons in the image capturing device **20** to react and form light images. The image capturing device **20** then converts the light images to digital signals through which the device **20** obtains digital raw frames **48** (FIG. **3**) comprising pixels. A pixel is a single point in a raw frame **48**. The raw frame **48** generally comprises several hundred thousands or millions of pixels arranged in rows and columns.

Examples of video sensors **46** used in the present invention include CMOS (Complementary Metal-Oxide Semiconductor) sensors and/or CCD (Charge-Coupled Device) sensors. However, the types of video sensors **46** should not be considered limiting, and any video sensor **46** compatible with the present system may be adopted.

The counting system **30** comprises three main components: (I) boot loader **32**; (2) system management and communication component **34**; and (3) counting component **36**.

The boot loader **32** is executed when the system is powered up and loads the main application program into memory **38** for execution.

The system management and communication component **34** includes task schedulers, database interface, recording functions, and TCP/IP or PPP communication protocols. The database interface includes modules for pushing and storing data generated from the counting component **36** to a database at a remote site. The recording functions provide operations such as writing user defined events to a database, sending emails, and video recording.

The counting component **36** is a key component of the system **10** and is described in further detail as follows.

2. The Counting Component.

In an illustrated embodiment of the present invention, at least one image capturing device **20** and the counting system **30** are integrated in a single image capturing and processing device. The single image capturing and processing device can be installed anywhere above the entrance or entrances to the facility **23**. Data output from the single image capturing and processing device can be transmitted through the system management and communication component **34** to the database for storage and further analysis.

FIG. **4** is a diagram showing the flow of processes of the counting component **36**. The processes are: (1) obtaining raw frames (block **100**); (2) rectification (block **102**); (3) disparity map generation (block **104**); (4) height map generation (block **106**); (5) object detection (block **108**); and (6) object tracking (block **110**).

Referring to FIGS. **1**-**4**, in block **100**, the image capturing device **20** obtains raw image frames **48** (FIG. **3**) at a given rate (such as for every 1 As second) of the field of view **44** from the video sensors **46**. Each pixel in the raw frame **48** records color and light intensity of a position in the field of view **44**. When the image capturing device **20** takes a snapshot, each video sensor **46** of the device **20** produces a different raw frame **48** simultaneously. One or more pairs of raw frames **48** taken simultaneously are then used to generate the height maps **56** for the field of view **44**, as will be described.

When multiple image capturing devices **20** are used, tracks **88** generated by each image capturing device **20** are merged before proceeding to block **102**.

Block **102** uses calibration data of the stereo cameras (not shown) stored in the image capturing device **20** to rectify raw stereo frames **48**. The rectification operation corrects lens distortion effects on the raw frames **48**. The calibration data include each sensor's optical center, lens distortion information, focal lengths, and the relative pose of one sensor with respect to the other. After the rectification, straight lines in the real world that have been distorted to curved lines in the raw stereo frames **48** are corrected and restored to straight lines. The resulting frames from rectification are called rectified frames **52**, **53** (FIG. **3**).

Block **104** creates a disparity map **50** (FIG. **3**) from each pair of rectified frames **52**, **53**. A disparity map **50** is an image map where each pixel comprises a disparity value. The term disparity was originally used to describe a 2-D vector between positions of corresponding features seen by the left and right eyes. Rectified frames **52**, **53** in a pair are compared to each other for matching features. The disparity is computed as the difference between positions of the same feature in frame **52** and frame **53**.

Block **106** converts the disparity map **50** to the height map **56**. Each pixel of the height map **56** comprises a height value and x-y coordinates, where the height value is represented by the greatest ground height of all the points in the same location in the field of view **44**. The height map **56** is sometimes referred to as a frame in the rest of the description.

2.1 Object Detection

Object detection (block **108**) is a process of locating candidate objects **58** in the height map **56**. One objective of the present invention is to detect human objects standing or walking in relatively flat areas. Because human objects of interest are much higher than the ground, local maxima of the height map **56** often represent heads of human objects or occasionally raised hands or other objects carried on the shoulders of human objects walking in counting zone **84**,**86** (FIG. **1**). Therefore, local maxima of the height map **56** are identified as positions of potential human object **58** detects. Each potential human object **58** detect is represented in the height map **56** by a local maximum with a height greater than a predefined threshold and all distances from other local maxima above a predefined range.

Occasionally, some human objects of interest do not appear as local maxima for reasons such as that the height map **56** is affected by false detection due to snow blindness effect in the process of generating the disparity map **50**, or that human objects of interests are standing close to taller objects such as walls or doors. To overcome this problem, the current invention searches in the neighborhood of the most recent local maxima for a suboptimal location as candidate positions for human objects of interest, as will be described later.

A run is a contiguous set of pixels on the same row of the height map **56** with the same non-zero height values. Each run is represented by a four-tuple (row, start-column, end-column, height). In practice, height map **56** is often represented by a set of runs in order to boost processing performance and object detection is also performed on the runs instead of the pixels.

Object detection comprises four stages: 1) background reconstruction; 2) first pass component detection; 3) second pass object detection; and 4) merging of closely located detects.

2.1.1 Component Definition and Properties

Pixel q is an eight-neighbor of pixel p if q and p share an edge or a vertex in the height map **56**, and both p and q have non-zero height values. A pixel can have as many as eight-neighbors.

A set of pixels E is an eight-connected component if for every pair of pixels Pi and Pi in E, there exists a sequence of pixels Pi' . . . , Pi such that all pixels in the sequence belong to the set E, and every pair of two adjacent pixels are eight neighbors to each other. Without further noting, an eight connected component is simply referred to as a connected component hereafter.

The connected component is a data structure representing a set of eight-connected pixels in the height map **56**. A connected component may represent one or more human objects of interest. Properties of a connected component include height, position, size, etc. Table 1 provides a list of properties associated with a connected component. Each property has an abbreviated name enclosed in a pair of parentheses and a description. Properties will be referenced by their abbreviated names hereafter.

TABLE 1

Number	Variable Name (abbreviated name)	Description
1	component ID (det_ID)	Identification of a component. In the first pass, componentID represents the component. In the second pass, componentID represents the parent component from which the current component is derived.
2	peak position (det_maxX, det_maxY)	Mass center of the pixels in the component having the greatest height value.
3	peak area (det_maxArea)	Number of pixels in the component having the greatest height value.
4	center (det_X, det_Y)	Mass center of all pixels of the component.
5	minimum size (det_minSize)	Size of the shortest side of two minimum rectangles that enclose the component at 0 and 45 degrees.
6	maximum size (det_maxSize)	Size of the longest side of two minimum rectangles that enclose the component at 0 and 45 degrees.
7	area (det_area)	Number of pixels of the component.
8	minimum height (det_minHeight)	Minimum height of all pixels of the component.
9	maximum height (det_maxHeight)	Maximum height of all pixels of the component.
10	height sum (det_htSum)	Sum of heights of pixels in a small square window centered at the center position of the component, the window having a configurable size.
11	Grouping flag (de_grouped)	A flag indicating whether the subcomponent still needs grouping.
12	background (det_inBackground)	A flag indicating whether the mass center of the component is in the background

TABLE 1-continued

Number	Variable Name (abbreviated name)	Description
13	the closest detection (det_closestDet)	Identifies a second pass component closest to the component but remaining separate after operation of "merging close detections".

Several predicate operators are applied to a subset of properties of the connected component to check if the subset of properties satisfies a certain condition. Component predicate operators include:

IsNoisy, which checks whether a connected component is too small to be considered a valid object detect **58**. A connected component is considered as "noise" if at least two of the following three conditions hold: 1) its det_minSize is less than two thirds of a specified minimum human body size, which is configurable in the range of [9,36] inches; 2) its det_area is less than four ninths of the area of a circle with its diameter equal to a specified minimum body size; and 3) the product of its det_minSize and det area is less than product of the specified minimum human body size and a specified minimum body area.

IsPointAtBoundaries, which checks whether a square window centered at the current point with its side equal to a specified local maximum search window size is intersecting boundaries of the height map **56**, or whether the connected component has more than a specific number of pixels in the dead zone **90**. If this operation returns true, the point being checked is considered as within the boundaries of the height map **56**.

NotSmallSubComponent, which checks if a subcomponent in the second pass component detection is not small. It returns true if its detrninxize is greater than a specified minimum human head size or its det_area is greater than a specified minimum human head area.

BigSubComponentSeed, which checks if a subcomponent seed in the second pass component detection is big enough to stop the grouping operation. It returns true if its detrninxize is greater than the specified maximum human head size or its det_area is greater than the specified maximum human head area.

SmallSubComponent, which checks if a subcomponent in the second pass component detection is small. It returns true if its detrninxize is less than the specified minimum human head size or its der area is less than the specified minimum human head area.

2.1.2 Background Reconstruction

The background represents static scenery in the field view **44** of the image capturing device **20** and is constructed from the height map **56**. The background building process monitors every pixel of every height map **56** and updates a background height map. A pixel may be considered as part of the static scenery if the pixel has the same non-zero height value for a specified percentage of time (e.g., 70%).

2.1.3 First-Pass Component Detection

First pass components are computed by applying a variant of an eight-connected image labeling algorithm on the runs of the height map **56**. Properties of first pass components are calculated according to the definitions in Table 1. Predicate operators are also applied to the first pass components. Those first pass components whose "IsNoise" predicate operator returns "true" are ignored without being passed on to the second pass component detection phase of the object detection.

2.1.4 Second Pass Object Detection

In this phase, height map local maxima, to be considered as candidate human detects, are derived from the first pass components in the following steps.

First, for each first pass component, find all eight connected subcomponents whose pixels have the same height. The deigrouped property of all subcomponents is cleared to prepare for subcomponent grouping and the deCID property of each subcomponent is set to the ID of the corresponding first pass component.

Second, try to find the highest ungrouped local maximal subcomponent satisfying the following two conditions: (1) the subcomponent has the highest height among all of the ungrouped subcomponents of the given first pass component, or the largest area among all of the ungrouped subcomponents of the given first pass component if several ungrouped subcomponents with the same highest height exist; and (2) the subcomponent is higher than all of its neighboring subcomponents. If such a subcomponent exists, use it as the current seed and proceed to the next step for further subcomponent grouping. Otherwise, return to step 1 to process the next first pass component in line.

Third, ifBigSubComponentSeed test returns true on the current seed, the subcomponent is then considered as a potential human object detect. Set the det grouped flag of the subcomponent to mark it as grouped and proceed to step 2 to look for a new seed. If the test returns false, proceed to the next step.

Fourth, try to find a subcomponent next to the current seed that has the highest height and meets all of the following three conditions: (I) it is eight-connected to the current seed; (2) its height is smaller than that of the current seed; and (3) it is not connected to a third subcomponent that is higher and it passes the NotSmallSubComponent test. If more than one subcomponent meets all of above conditions, choose the one with the largest area. When no subcomponent meets the criteria, set the deigrouped property of the current seed to "grouped" and go to step 2. Otherwise, proceed to the next step.

Fifth, calculate the distance between centers of the current seed and the subcomponent found in the previous step. If the distance is less than the specified detection search range or the current seed passes the SmallSubComponent test, group the current seed and the subcomponent together and update the properties of the current seed accordingly. Otherwise, set the det_grouped property of the current seed as "grouped". Return to step 2 to continue the grouping process until no further grouping can be done.

2.1.5 Merging Closely Located Detections

Because the image capturing device **20** is mounted on the ceiling of the facility entrance (FIG. **1**), a human object of interest is identified by a local maximum in the height map. Sometimes more than one local maxima detection is generated from the same human object of interest. For example, when a human object raises both of his hands at the same time, two closely located local maxima may be detected. Therefore, it is necessary to merge closely located local maxima.

The steps of this phase are as follows.

First, search for the closest pair of local maxima detections. If the distance between the two closest detections is greater than the specified detection merging distance, stop and exit the process. Otherwise, proceed to the next step.

Second, check and process the two detections according to the following conditions in the given order. Once one condition is met, ignore the remaining conditions and proceed to the next step:

a) if either but not all detection is in the background, ignore the one in the background since it is most likely a static object (the local maximum in the foreground has higher priority over the one in the background);

b) if either but not all detection is touching edges of the height map **56** or dead zones, delete the one that is touching edges of the height map **56** or dead zones (a complete local maximum has higher priority over an incomplete one);

c) if the difference between det rnaxlleights of detections is smaller than a specified person height variation threshold, delete the detection with significantly less 3-D volume (e.g., the product of det_maxHeight and det_masArea for one connected component is less than two thirds of the product for the other connected component) (a strong local maximum has higher priority over a weak one);

d) if the difference between maximum heights of detections is more than one foot, delete the detection with smaller det_maxHeight if the detection with greater height among the two is less than the specified maximum person height, or delete the detection with greater det_maxHeight if the maximum height of that detection is greater than the specified maximum person height (a local maxima with a reasonable height has higher priority over a local maximum with an unlikely height);

e) delete the detection whose det area is twice as small as the other (a small local maximum close to a large local maximum is more likely a pepper noise);

f) if the distance between the two detections is smaller than the specified detection search range, merge the two detections into one (both local maxima are equally good and close to each other);

g) keep both detections if the distance between the two detections is larger than or equal to the specified detection search range (both local maxima are equally good and not too close to each other). Update the det., closestDet attribute for each detection with the other detection's ID.

Then, return to step 1 to look for the next closest pair of detections.

The remaining local maxima detections after the above merging process are defined as candidate object detects **58**, which are then matched with a set of existing tracks **74** for track extension, or new track initiation if no match is found.

2.2 Object Tracking

Object tracking (block **110** in FIG. **1**) uses objects detected in the object detection process (block **108**) to extend existing tracks **74** or create new tracks **80**. Some short, broken tracks are also analyzed for possible track repair operations.

To count human objects using object tracks, zones **82** are delineated in the height map **56**. Door zones **84** represent door areas around the facility **23** to the entrance. Interior zones **86** represent interior areas of the facility. A track **76** traversing from the door zone **84** to the interior zone **86** has a potential "in" count. A track **76** traversing to the door zone **84** from the interior zone **86** has a potential "out" count. If a track **76** traverses across zones **82** multiple times, there can be only one potential "in" or "out" count depending on the direction of the latest zone crossing.

As illustrated in FIG. **5**, the process of object tracking **110** comprises the following phases: 1) analysis and processing of old tracks (block **120**); 2) first pass matching between tracks and object detects (block **122**); 3) suboptimal localization of unpaired tracks (block **124**); 4) second pass matching between tracks and object detects (block **126**); and 5) track updating or creation (block **128**).

An object track **76** can be used to determine whether a human object is entering or leaving the facility, or to derive properties such as moving speed and direction for human objects being tracked.

Object tracks **76** can also be used to eliminate false human object detections, such as static signs around the entrance area. If an object detect **58** has not moved and its associated track **76** has been static for a relatively long time, the object detect **58** will be considered as part of the background and its track **76** will be processed differently than normal tracks (e.g., the counts created by the track will be ignored).

Object tracking **110** also makes use of color or gray level intensity information in the frames **52**, **53** to search for best match between tracks **76** and object detects **58**. Note that the color or the intensity information is not carried to disparity maps **50** or height maps **56**.

The same technique used in the object tracking can also be used to determine how long a person stands in a checkout line.

2.2.1 Properties of Object Track

Each track **76** is a data structure generated from the same object being tracked in both temporal and spatial domains and contains a list of 4-tuples (x, y, t, h) in addition to a set of related properties, where h, x and y present the height and the position of the object in the field of view **44** at time t. (x, y, h) is defined in a world coordinate system with the plane formed by x and y parallel to the ground and the h axis vertical to the ground. Each track can only have one position at any time. In addition to the list of 4-tuples, track **76** also has a set of properties as defined in Table 2 and the properties will be referred to later by their abbreviated names in the parentheses:

TABLE 2

Number	Variable Name	Description
1	ID number (trk_ID)	A unique number identifying the track.
2	track state (trk_state)	A track could be in one of three states: active, inactive and deleted. Being active means the track is extended in a previous frame, being inactive means the track is not paired with a

TABLE 2-continued

Number	Variable Name	Description
		detect in a previous frame, and being deleted means the track is marked for deletion.
3	start point (trk_start)	The initial position of the track (Xs, Ys, Ts, Hs).
4	end point (trk_end)	The end position of the track (Xe, Ye, Te, He).
5	positive Step Numbers (trk_posNum)	Number of steps moving in the same direction as the previous step.
6	positive Distance (trk_posDist)	Total distance by positive steps.
7	negative Step Numbers (trk_negNum)	Number of steps moving in the opposite direction to the previous step.
8	negative Distance (trk_negDist)	Total distance by negative steps.
9	background count (trk_backgroundCount)	The accumulative duration of the track in background.
10	track range (trk_range)	The length of the diagonal of the minimal rectangle covering all of the track's points.
11	start zone (trk_startZone)	A zone number representing either door zone or interior zone when the track is created.
12	last zone (trk_lastZone)	A zone number representing the last zone the track was in.
13	enters (trk_enters)	Number of times the track goes from a door zone to an interior zone.
14	exits (trk_exits)	Number of times the track goes from an interior zone to a door zone.
15	total steps (trk_totalSteps)	The total non-stationary steps of the track.
16	high point steps (trk_higbPtSteps)	The number of non-stationary steps that the track has above a maximum person height (e.g. 85 inches).
17	low point steps (trk_lowPtSteps)	The number of non-stationary steps below a specified minimumn person height.
18	maximum track height (trk_maxTrackHt)	The maximum height of the track.
19	non-local maximum detection point (trk_nonMaxDetNum)	The accumulative duration of the time that the track has from non-local maximum point in the height map and that is closest to any active track.
20	moving vector (trk_movingVec)	The direction and offset from the closest point in time to the current point with the offset greater than the minimwn body size.
21	following track (trk_followingTrack)	The ID of the track that is following closely. If there is a track following closely, the distance between these two tracks don't change a lot, and the maximum height of the front track is less than a specified height for shopping carts, then the track in the front may be considered as made by a shopping cart.
22	minimum following distance (trk_minFollowingDist)	The minimum distance from this track to the following track at a point of time.
23	maximum following distance (trk_maxFollowingDist)	The maximum distance from this track to the following track at a point of time.
24	following duration (trk_voteFollowing)	The time in frames that the track is followed by the track specified in trk_followingTrack.
25	most recent track (trk_lastCollidingTrack)	The id of a track whose detection t was once very close to this track's non-local minimum candidate extending position.
26	number of merged tracks (trk_mergedTracks)	The number of small tracks that this track is made of through connection of broken tracks.
27	number of small track searches (trk_smallSearches)	The number of small track search ranges used in merging tracks.
28	Mirror track (trk_mirrorTrack)	The ID of the track that is very close to this track and that might be the cause of this track. This track itself has to be from a non-local maximum detection created by a blind search, or its height has to be less than or equal to the specified minimum person height in order to be qualified as a candidate for false tracks.
29	Mirror track duration (trk_voteMirrorTrack)	The time in frames that the track is a candidate for false tracks and is closely accompanied by the track specified in trk_mirrorTrack within a distance of the specified maximum person width.
30	Maximum minor track distance (trk_maxMirrorDist)	The maximum distance between the track and the track specified in trk_mirrorTrack.

2.2.2 Track-Related Predicative Operations

Several predicate operators are defined in order to obtain the current status of the tracks **76**. The predicate operators are applied to a subset of properties of a track **76** to check if the subset of properties satisfies a certain condition. The predicate operators include:

IsNoisyNow, which checks if track bouncing back and forth locally at the current time. Specifically, a track **76** is considered noisy if the track points with a fixed number of frames in the past (specified as noisy track duration) satisfies one of the following conditions:

a) the range of track **76** (trkrange) is less than the specified noisy track range, and either the negative distance (trk_negDist) is larger than two thirds of the positive distance (trk_posDist) or the negative steps (trk_negNum) are more than two thirds of the positive steps (trk_posNum);

b) the range of track **76** (trkrange) is less than half of the specified noisy track range, and either the negative distance (trk_negDist) is larger than one third of the positive distance (trk_posDist) or the negative steps (trk_negNum) are more than one third of the positive steps (trk_posNum).

WholeTrackIsNoisy: a track **76** may be noisy at one time and not noisy at another time.

This check is used when the track **76** was created a short time ago, and the whole track **76** is considered noisy if one of the following conditions holds:

a) the range of track **76** (trkrange) is less than the specified noisy track range, and either the negative distance (trk_negDist) is larger than two thirds of the positive distance (trk_posDist) or the negative steps (trk_negNum) are more than two thirds of the positive steps (trk_posNum);

b) the range of track **76** (trkrange) is less than half the specified noisy track range, and either the negative distance trk_negDist) is larger than one third of the positive distance (trk_posDist) or the negative steps (trk_negNum) are more than one third of the positive steps (trk_posNum).

IsSameTrack, which check if two tracks **76**, **77** are likely caused by the same human object. All of the following three conditions have to be met for this test to return true: (a) the two tracks **76**, **77** overlap in time for a minimum number of frames specified as the maximum track timeout; (b) the ranges of both tracks **76**, **77** are above a threshold specified as the valid counting track span; and (c) the distance between the two tracks **76**, **77** at any moment must be less than the specified minimum person width.

IsCountIgnored: when the track **76** crosses the counting zones, it may not be created by a human object of interest. The counts of a track are ignored if one of the following conditions is met:

Invalid Tracks: the absolute difference between trk_exits and trk_enters is not equal to one.

Small Tracks: trkrange is less than the specified minimum counting track length.

Unreliable Merged Tracks: trkrange is less than the specified minimum background counting track length as well as one of the following: trk_mergedTracks is equal to trk_smallSearches, or trk_backgroundCount is more than 80% of the life time of the track **76**, or the track **76** crosses the zone boundaries more than once.

High Object Test: trk_highPtSteps is larger than half oftrk_totalSteps.

Small Child Test: trk_lowPtSteps is greater than ¾ of trk_totalSteps, and trk_maxTrackHt is less than or equal to the specified minimum person height.

Shopping Cart Test: trk_voteFollowing is greater than 3, trk_minFollowingDist is more than or equal to 80% of trk_maxFollowingDist, and trk_maxTrackHt is less than or equal to the specified shopping cart height.

False Track test: trk_voteMirrorTrack is more than 60% of the life time of the track **76**, and trk_maxMirrorTrackDist is less than two thirds of the specified maximum person width or trk_totalVoteMirrorTrack is more than 80% of the life time of the track **76**.

2.2.3 Track Updating Operation

Referring to FIG. **12**, each track **76** is updated with new information on its position, time, and height when there is a best matching human object detect **58** in the current height map **56** for First, set trk_state of the track **76** to **1** (block **360**).

Second, for the current frame, obtain the height by using median filter on the most recent three heights of the track **76** and calculate the new position **56** by averaging on the most recent three positions of the track **76** (block **362**).

Third, for the current frame, check the noise status using track predicate operator IsNoisyNow. If true, mark a specified number of frames in the past as noisy. In addition, update noise related properties of the track **76** (block **364**).

Fourth, update the span of the track **76** (block **366**).

Fifth, if one of the following conditions is met, collect the count carried by track **76** (block **374**):

a) the track **76** is not noisy at the beginning, but it has been noisy for longer than the specified stationary track timeout (block **368**); or

b) the track **76** is not in the background at the beginning, but it has been in the background for longer than the specified stationary track timeout (block **370**).

Finally, update the current zone information (block **372**).

2.2.4 Track Prediction Calculation

It helps to use a predicted position of the track **76** when looking for best matching detect **58**. The predicted position is calculated by linear extrapolation on positions of the track **76** in the past three seconds.

2.2.5 Analysis and Processing of Old Track

This is the first phase of object tracking. Active tracks **88** are tracks **76** that are either created or extended with human object detects **58** in the previous frame. When there is no best matching human object detect **58** for the track **76**, the track **76** is considered as inactive.

This phase mainly deals with tracks **76** that are inactive for a certain period of time or are marked for deletion in previous frame **56**. Track analysis is performed on tracks **76** that have been inactive for a long time to decide whether to group them with existing tracks **74** or to mark them for deletion in the next frame **56**. Tracks **76** are deleted if the tracks **76** have been marked for deletion in the previous frame **56**, or the tracks **76** are inactive and were created a very short period of time before. If the counts of the soon-to-be deleted tracks **76** shall not be ignored according to the IsCountIgnored predicate operator, collect the counts of the tracks **76**.

2.2.6 First Pass Matching Between Tracks and Detects

After all tracks **76** are analyzed for grouping or deletion, this phase searches for optimal matches between the human object detects **58** (i.e. the set of local maxima found in the object detection phase) and tracks **76** that have not been deleted.

First, check every possible pair of track **76** and detect **58** and put the pair into a candidate list if all of the following conditions are met:

1) The track **76** is active, or it must be long enough (e.g. with more than three points), or it just became inactive a short period of time ago (e.g. it has less than three frames);

2) The smaller of the distances from center of the detect **58** to the last two points of the track **76** is less than two thirds of the specified detection search range when the track **76** hasn't

moved very far (e.g. the span of the track **76** is less than the specified minimum human head size and the track **76** has more than 3 points);

3) If the detect **58** is in the background, the maximum height of the detect **58** must be greater than or equal to the specified minimum person height;

4) If the detect **58** is neither in the background nor close to dead zones or height map boundaries, and the track **76** is neither in the background nor is noisy in the previous frame, and a first distance from the detect **58** to the predicted position of the track **76** is less than a second distance from the detect **58** to the end position of the track **76**, use the first distance as the matching distance. Otherwise, use the second distance as the matching distance. The matching distance has to be less than the specified detection search range;

5) The difference between the maximum height of the detect **58** and the height oblast point of the track **76** must be less than the specified maximum height difference; and

6) If either the last point off-track **76** or the detect **58** is in the background, or the detect **58** is close to dead zones or height map boundaries, the distance from the track **76** to the detect **58** must be less than the specified background detection search range, which is generally smaller than the threshold used in condition (4).

Sort the candidate list in terms of the distance from the detect **58** to the track **76** or the height difference between the detect **58** and the track **76** (if the distance is the same) in ascending order.

The sorted list contains pairs of detects **58** and tracks **76** that are not paired. Run through the whole sorted list from the beginning and check each pair. If either the detect **58** or the track **76** of the pair is marked "paired" already, ignore the pair. Otherwise, mark the detect **58** and the track **76** of the pair as "paired".

2.2.7 Search of Suboptimal Location for Unpaired Tracks

Due to sparseness nature of the disparity map **50** and the height map **56**, some human objects may not generate local maxima in the height map **56** and therefore may be missed in the object detection process **108**. In addition, the desired local maxima might get suppressed by a neighboring higher local maximum from a taller object. Thus, some human object tracks **76** may not always have a corresponding local maximum in the height map **56**. This phase tries to resolve this issue by searching for a suboptimal location for a track **76** that has no corresponding local maximum in the height map **56** at the current time. Tracks **76** that have already been paired with a detect **58** in the previous phase might go through this phase too to adjust their locations if the distance between from end of those tracks to their paired detects is much larger than their steps in the past. In the following description, the track **76** currently undergoing this phase is called Track A. The search is performed in the following steps.

First, referring to FIG. **7**, if Track A is deemed not suitable for the suboptimal location search operation (i.e., it is inactive, or it's in the background, or it's close to the boundary of the height map **56** or dead zones, or its height in last frame was less than the minimum person height (block **184**)), stop the search process and exit. Otherwise, proceed to the next step.

Second, if Track A has moved a few steps (block **200**) (e.g., three steps) and is paired with a detection (called Detection A) (block **186**) that is not in the background and whose current step is much larger than its maximum moving step within a period of time in the past specified by a track time out parameter (block **202**,**204**), proceed to the next step. Otherwise, stop the search process and exit.

Third, search around the end point of Track A in a range defined by its maximum moving steps for a location with the largest height sum in a predefined window and call this location Best Spot A (block **188**). If there are some detects **58** deleted in the process of merging of closely located detects in the object detection phase and Track A is long in either the spatial domain or the temporal domain (e.g. the span of Track A is greater than the specified noisy track span threshold, or Track A has more than three frames) (block **190**), find the closest one to the end point of Track too. If its distance to the end point of Track A is less than the specified detection search range (block **206**), search around the deleted component for the position with the largest height sum and call it Best Spot AI (block **208**). If neither Best Spot A nor Best Spot AI exists, stop the search process and exit. If both Best Spot A and Best Spot AI exist, choose the one with larger height sum. The best spot selected is called suboptimal location for Track A. If the maximum height at the suboptimal location is greater than the predefined maximum person height (block **192**), stop the search and exit. If there is no current detection around the suboptimal location (block **194**), create a new detect **58** (block **214**) at the suboptimal location and stop the search. Otherwise, find the closest detect **58** to the suboptimal location and call it Detection B (block **196**). If Detection B is the same detection as Detection A in step 2 (block **198**), update Detection A's position with the suboptimal location (block **216**) and exit the search. Otherwise, proceed to the next step.

Fourth, referring to FIG. **8**, if Detection B is not already paired with a track **76** (block **220**), proceed to the next step. Otherwise, call the paired track of the Detection B as Track B and perform one of the following operations in the given order before exiting the search:

1) When the suboptimal location for Track A and Detection B are from the same parent component (e.g. in the support of the same first pass component) and the distance between Track A and Detection B is less than half of the specified maximum person width, create a new detect **58** at the suboptimal location (block **238**) if all of the following three conditions are met: (i) the difference between the maximum heights at the suboptimal location and Detection B is less than a specified person height error range; (ii) the difference between the height sums at the two locations is less than half of the greater one; (iii) the distance between them is greater than the specified detection search range and the trk_range values of both Track A and Track B are greater than the specified noisy track offset. Otherwise, ignore the suboptimal location and exit;

2) If the distance between the suboptimal location and Detection B is greater than the specified detection search range, create a new detect **58** at the suboptimal location and exit;

3) If Track A is not sizable in both temporal and spatial domains (block **226**), ignore the suboptimal location;

4) If Track B is not sizable in both temporal and spatial domain (block **228**), detach Track B from Detection B and update Detection B's position with the suboptimal location (block **246**). Mark Detection B as Track A's closest detection;

5) Look for best spot for Track B around its end position (block **230**). If the distance between the best spot for Track B and the suboptimal location is less than the specified detection search range (block **232**) and the best spot for Track B has a larger height sum, replace the suboptimal location with the best spot for Track B (block **233**). If the distance between is larger than the specified detection search range, create a detect **58** at the best spot for Track B (block **250**). Update Detection A's location with the suboptimal location if Detection A exists.

Fifth, if the suboptimal location and Detection B are not in the support of the same first pass component, proceed to the

next step. Otherwise create a new detection at the suboptimal location if their distance is larger than half of the specified maximum person width, or ignore the suboptimal location and mark Detection B as Track A's closest detection otherwise.

Finally, create a new detect **58** at suboptimal location and mark Detection B as Track A's closest detection (block **252**) if their distance is larger than the specified detection search range. Otherwise, update Track A's end position with the suboptimal location (block **254**) if the height sum at the suboptimal location is greater than the height sum at Detection B, or mark Detection Bas Track A's closest detection otherwise.

2.2.8 Second Pass Matching Between Tracks and Detects

After the previous phase, a few new detections may be added and some paired detects **72** and tracks **76** become unpaired again. This phase looks for the optimal match between current unpaired detects **72** and tracks **76** as in the following steps.

For every pair of track **76** and detect **58** that remain unpaired, put the pair into a candidate list if all of the following five conditions are met:

1) the track **76** is active (block **262** in FIG. **9**);

2) the distance from detect **58** to the end point of the track **76** (block **274**) is smaller than two thirds of the specified detection search range (block **278**) when the track doesn't move too far (e.g. the span of the track **76** is less than the minimal head size and the track **76** has more than three points (block **276**));

3) if the detect **58** is in the background (block **280**), the maximum height of the detect **58** must be larger than or equal to the specified minimum person height (block **282**);

4) the difference between the maximum height and the height of the last point of the track **76** is less than the specified maximum height difference (block **284**);

5) the distance from the detect **58** to the track **76** must be smaller than the specified background detection search range, if either the last point of the track **76** or the detect **58** is in background (block **286**), or the detect **58** is close to dead zones or height map boundaries (block **288**); or if not, the distance from the detect **58** to the track **76** must be smaller than the specified detection search range (block **292**).

Sort the candidate list in terms of the distance from the detect **58** to the track **76** or the height difference between the two (if distance is the same) in ascending order (block **264**).

The sorted list contains pairs of detects **58** and tracks **76** which are not paired at all at the beginning. Then run through the whole sorted list from the beginning and check each pair. If either the detect **58** or the track **76** of the pair is marked "paired" already, ignore the pair. Otherwise, mark the detect **58** and the track **76** of the pair as "paired" (block **270**).

2.2.9 Track Update or Creation

After the second pass of matching, the following steps are performed to update old tracks or to create new tracks:

First, referring to FIG. **10**, for each paired set of track **76** and detect **58** the track **76** is updated with the information of the detect **58** (block **300**,**302**).

Second, create a new track **80** for every detect **58** that is not matched to the track **76** if the maximum height of the detect **58** is greater than the specified minimum person height, and the distance between the detect **58** and the closest track **76** of the detect **58** is greater than the specified detection search range (block **306**,**308**). When the distance is less than the specified detection merge range and the detect **58** and the closest track **76** are in the support of the same first pass component (i.e., the detect **58** and the track **76** come from the same first pass component), set the trk_IastCollidingTrack of the closest track **76** to the ID of the newly created track **80** if there is one (block **310**,**320**).

Third, mark each unpaired track **77** as inactive (block **324**). If that track **77** has a marked closest detect and the detect **58** has a paired track **76**, set the trk_IastCollidingTrack property of the current track **77** to the track ID of the paired track **76** (block **330**).

Fourth, for each active track **88**, search for the closest track **89** moving in directions that are at most thirty degrees from the direction of the active track **88**. If the closest track **89** exists, the track **88** is considered as closely followed by another track, and "Shopping Cart Test" related properties of the track **88** are updated to prepare for "Shopping Cart Test" when the track **88** is going to be deleted later (block **334**).

Finally, for each active track **88**, search for the closest track **89**. If the distance between the two is less than the specified maximum person width and either the track **88** has a marked closest detect or its height is less than the specified minimum person height, the track **88** is considered as a less reliable false track. Update "False Track" related properties to prepare for the "False Track" test later when the track **88** is going to be deleted later (block **338**).

As a result, all of the existing tracks **74** are either extended or marked as inactive, and new tracks **80** are created.

2.2.10 Track Analysis

Track analysis is applied whenever the track **76** is going to be deleted. The track **76** will be deleted when it is not paired with any detect for a specified time period. This could happen when a human object moves out of the field view **44**, or when the track **76** is disrupted due to poor disparity map reconstruction conditions such as very low contrast between the human object and the background.

The goal of track analysis is to find those tracks that are likely continuations of some soon-to-be deleted tracks, and merge them. Track analysis starts from the oldest track and may be applied recursively on newly merged tracks until no tracks can be further merged. In the following description, the track that is going to be deleted is called a seed track, while other tracks are referred to as current tracks. The steps of track analysis are as follows:

First, if the seed track was noisy when it was active (block **130** in FIG. **6**), or its trkrange is less than a specified merging track span (block **132**), or its trk_IastCollidingTrack does not contain a valid track ID and it was created in less than a specified merging track time period before (block **134**), stop and exit the track analysis process.

Second, examine each active track that was created before the specified merging track time period and merge an active track with the seed track if the "Is the Same Track" predicate operation on the active track (block **140**) returns true.

Third, if the current track satisfies all of the following three initial testing conditions, proceed to the next step. Otherwise, if there exists a best fit track (definition and search criteria for the best fit track will be described in forthcoming steps), merge the best fit track with the seed track (block **172**, **176**). If there is no best fit track, keep the seed track if the seed track has been merged with at least one track in this operation (block **178**), or delete the seed track (block **182**) otherwise. Then, exit the track analysis.

The initial testing conditions used in this step are: (1) the current track is not marked for deletion and is active long enough (e.g. more than three frames) (block **142**); (2) the current track is continuous with the seed track (e.g. it is created within a specified maximum track timeout of the end point of the seed track) (block **144**); (3) if both tracks are short in space (e.g., the trkrange properties of both tracks are less

than the noisy track length threshold), then both tracks should move in the same direction according to the relative offset of the trk_start and trk_end properties of each track (block **146**).

Fourth, merge the seed track and the current track (block **152**). Return to the last step if the current track has collided with the seed track (i.e., the trk_lastCollidingTrack of the current track is the trk_ID of the seed track). Otherwise, proceed to the next step.

Fifth, proceed to the next step if the following two conditions are met at the same time, otherwise return to step 3: (1) if either track is at the boundaries according to the "is at the boundary" checking (block **148**), both tracks should move in the same direction; and (2) at least one track is not noisy at the time of merging (block **150**). The noisy condition is determined by the "is noisy" predicate operator.

Sixth, one of two thresholds coming up is used in distance checking. A first threshold (block **162**) is specified for normal and clean tracks, and a second threshold is specified for noisy tracks or tracks in the background. The second threshold (block **164**) is used if either the seed track or the current track is unreliable (e.g. at the boundaries, or either track is noisy, or trkranges of both tracks are less than the specified noisy track length threshold and at least one track is in the background) (block **160**), otherwise the first threshold is used. If the shortest distance between the two tracks during their overlapping time is less than the threshold (block **166**), mark the current track as the best fit track for the seed track (block **172**) and if the seed track does not have best fit track yet or the current track is closer to the seed track than the existing best fit track (block **170**). Go to step 3.

2.2.11 Merging of Tracks

This operation merges two tracks into one track and assigns the merged track with properties derived from the two tracks. Most properties of the merged track are the sum of the corresponding properties of the two tracks but with the following exceptions:

Referring to FIG. **11**, trk_enters and trk_exits properties of the merged track are the sum of the corresponding properties of the tracks plus the counts caused by zone crossing from the end point ozone track to the start point of another track, which compensates the missing zone crossing in the time gap between the two tracks (block **350**).

If a point in time has multiple positions after the merge, the final position is the average (block **352**).

The trk_start property of the merged track has the same trk_start value as the newer track among the two tracks being merged, and the trk_end property of the merged track has the same trk_end value as the older track among the two (block **354**).

The buffered raw heights and raw positions of the merged track are the buffered raw heights and raw positions of the older track among the two tracks being merged (block **356**).

As shown in FIG. **13**, an alternative embodiment of the present invention may be employed and may comprise a system **210** having an image capturing device **220**, a reader device **225** and a counting system **230**. In the illustrated embodiment, the at least one image capturing device **220** may be mounted above an entrance or entrances **221** to a facility **223** for capturing images from the entrance or entrances **221**. The area captured by the image capturing device **220** is field of view **244**. Each image captured by the image capturing device **220**, along with the time when the image is captured, is a frame **248**. As described above with respect to image capturing device **20** for the previous embodiment of the present invention, the image capturing device **220** may be video based. The manner in which object data is captured is not meant to be limiting so long as the image capturing device **220** has the ability to track objects in time across a field of view **244**. The object data **261** may include many different types of information, but for purposes of this embodiment of the present invention, it includes information indicative of a starting frame, an ending frame, and direction.

For exemplary purposes, the image capturing device **220** may include at least one stereo camera with two or more video sensors **246** (similar to the image capturing device shown in FIG. **2**), which allows the camera to simulate human binocular vision. A pair of stereo images comprises frames **248** taken by each video sensor **246** of the camera. The image capturing device **220** converts light images to digital signals through which the device **220** obtains digital raw frames **248** comprising pixels. The types of image capturing devices **220** and video sensors **246** should not be considered limiting, and any image capturing device **220** and video sensor **246** compatible with the present system may be adopted.

For capturing tag data **226** associated with RFID tags, such as name tags that may be worn by an employee or product tags that could be attached to pallets of products, the reader device **225** may employ active RFID tags **227** that transmit their tag information at a fixed time interval. The time interval for the present invention will typically be between 1 and 10 times per second, but it should be obvious that other time intervals may be used as well. In addition, the techniques for transmitting and receiving RFID signals are well known by those with skill in the art, and various methods may be employed in the present invention without departing from the teachings herein. An active RFID tag is one that is self-powered, i.e., not powered by the RF energy being transmitted by the reader. To ensure that all RFID tags **227** are captured, the reader device **225** may run continuously and independently of the other devices and systems that form the system **210**. It should be evident that the reader device **225** may be replaced by a device that uses other types of RFID tags or similar technology to identify objects, such as passive RFID, ultrasonic, or infrared technology. It is significant, however, that the reader device **225** has the ability to detect RFID tags, or other similar devices, in time across a field of view **228** for the reader device **225**. The area captured by the reader device **225** is the field of view **228** and it is preferred that the field of view **228** for the reader device **225** be entirely within the field of view **244** for the image capturing device **220**.

The counting system **230** processes digital raw frames **248**, detects and follows objects **258**, and generates tracks associated with objects **258** in a similar manner as the counting system **30** described above. The counting system **230** may be electronically or wirelessly connected to at least one image capturing device **220** and at least one reader device **225** via a local area or wide area network. Although the counting system **230** in the present invention is located remotely as part of a central server, it should be evident to those with skill in the art that all or part of the counting system **230** may be (i) formed as part of the image capturing device **220** or the reader device **225**, (ii) stored on a "cloud computing" network, or (iii) stored remotely from the image capturing device **220** and reader device **225** by employing other distributed processing techniques. In addition, the RFID reader **225**, the image capturing device **220**, and the counting system **230** may all be integrated in a single device. This unitary device may be installed anywhere above the entrance or entrances to a facility **223**. It should be understood, however, that the hardware and methodology that is used for detecting and tracking objects is not limited with respect to this embodiment of the present invention. Rather, it is only important that objects are detected and tracked and the data associated with objects **258** and tracks is used in combination with tag data **226** from the

reader device **225** to separately count and track anonymous objects **320** and defined objects **322**, which are associated with an RFID tag **227**.

To transmit tag data **226** from the reader device **225** to a counting system **230**, the reader device **225** may be connected directly to the counting system **230** or the reader device **225** may be connected remotely via a wireless or wired communications network, as are generally known in the industry. It is also possible that the reader device **225** may send tag data to the image capturing device, which in turn transmits the tag data **226** to the counting system **230**. The tag data **226** may be comprised of various information, but for purposes of the present invention, the tag data **226** includes identifier information, signal strength information and battery strength information.

To allow the counting system **230** to process traffic data **260**, tag data **226** and object data **261** may be pulled from the reader device **225** and the image capturing device **220** and transmitted to the counting system **230**. It is also possible for the reader device **225** and the image capturing device **220** to push the tag data **226** and object data **261**, respectively, to the counting system **230**. It should be obvious that the traffic data **260**, which consists of both tag data **226** and object data **261**, may also be transmitted to the counting system via other means without departing from the teachings of this invention. The traffic data **260** may be sent as a combination of both tag data **226** and object data **261** and the traffic data **260** may be organized based on time.

The counting system **230** separates the traffic data **260** into tag data **226** and object data **261**. To further process the traffic data **260**, the counting system **230** includes a listener module **310** that converts the tag data **226** into sequence records **312** and the object data **261** into track records **314**. Moreover, the counting system **230** creates a sequence array **352** comprised of all of the sequence records **312** and a track array **354** comprised of all of the track records **314**. Each sequence record **312** may consist of (1) a tag ID **312***a*, which may be an unsigned integer associated with a physical RFID tag **227** located within the field of view **228** of a reader device **220**; (2) a startTime **312***b*, which may consist of information indicative of a time when the RFID tag **227** was first detected within the field of view **228**; (3) an endTime, which may consist of information indicative of a time when the RFID tag **227** was last detected within the field of view **228** of the reader device **220**; and (4) an array of references to all tracks that overlap a particular sequence record **312**. Each track record **314** may include (a) a counter, which may be a unique ID representative of an image capturing device **220** associated with the respective track; (b) a direction, which may consist of information that is representative of the direction of movement for the respective track; (c) startTime, which may consist of information indicative of a time when the object of interest was first detected within the field of view **244** of the image capturing device **220**; (d) endTime, which may consist of information indicative of a time when the object of interest left the field of view **244** of the image capturing device **220**; and (e) tagID, which (if non-zero) may include an unsigned integer identifying a tag **227** associated with this track record **314**.

To separate and track anonymous objects **320**, such as shoppers or customers, and defined objects **322**, such as employees and products, the counting system **220** for the system must determine which track records **314** and sequence records **312** match one another and then the counting system **220** may subtract the matching track records **312** from consideration, which means that the remaining (unmatched) track records **314** relate to anonymous objects **320** and the track records **312** that match sequence records **314** relate to defined objects **322**.

To match track records **314** and sequence records **312**, the counting system **220** first determines which track records **314** overlap with particular sequence records **312**. Then the counting system **220** creates an array comprised of track records **312** and sequence records **314** that overlap, which is known as a match record **316**. In the final step, the counting system **220** iterates over the records **312**, **314** in the match record **316** and determines which sequence records **312** and track records **314** best match one another. Based on the best match determination, the respective matching track record **314** and sequence record **312** may be removed from the match record **316** and the counting system will then iteratively move to the next sequence record **312** to find the best match for that sequence record **312** until all of the sequence records **312** and track records **314** in the match record **316** have matches, or it is determined that no match exists.

The steps for determining which sequence records **312** and track records **314** overlap are shown in FIG. **15**. To determine which records **312**, **314** overlap, the counting system **220** iterates over each sequence record **312** in the sequence array **352** to find which track records overlap with a particular sequence records **312**; the term "overlap" generally refers to track records **314** that have startTimes that are within a window defined by the startTime and endTime of a particular sequence records **312**. Therefore, for each sequence record **312**, the counting system **230** also iterates over each track record **314** in the track array **354** and adds a reference to the respective sequence record **312** indicative of each track record **314** that overlaps that sequence record **314**. Initially, the sequence records have null values for overlapping track records **314** and the track records have tagID fields set to zero, but these values are updated as overlapping records **312**, **314** are found. The iteration over the track array **254** stops when a track record **314** is reached that has a startTime for the track record **314** that exceeds the endTime of the sequence record **312** at issue.

To create an array of "overlapped" records **312**, **314** known as match records **316**, the counting system **230** iterates over the sequence array **352** and for each sequence record **312***a*, the counting system **230** compares the track records **314***a* that overlap with that sequence record **312***a* to the track records **314***b* that overlap with the next sequence record **312***b* in the sequence array **352**. As shown in FIG. **16**, a match record **316** is then created for each group of sequence records **312** whose track records **314** overlap. Each match record **316** is an array of references to all sequence records **312** whose associated track records **314** overlap with each other and the sequence records **312** are arranged in earliest-to-latest startTime order.

The final step in matching sequence records **312** and track records **314** includes the step of determining which sequence records **312** and track records **314** are the best match. To optimally match records **312**, **314**, the counting system **230** must consider direction history on a per tag **227** basis, i.e., by mapping between the tagID and the next expected match direction. The initial history at the start of a day (or work shift) is configurable to either "in" or "out", which corresponds to employees initially putting on their badges or name tags outside or inside the monitored area.

To optimally match records **312**, **314**, a two level map data structure, referred to as a scoreboard **360**, may be built. The scoreboard **360** has a top level or sequencemap **362** and a bottom level or trackmap **364**. Each level **362**, **364** has keys **370**, **372** and values **374**, **376**. The keys **370** for the top level **362** are references to the sequence array **352** and the values

374 are the maps for the bottom level 364. The keys for the bottom level 364 are references to the track array 354 and the values 376 are match quality scores 380. As exemplified in FIG. 17, the match quality scores are determined by using the following algorithm.

1) Determine if the expected direction for the sequence record is the same as the expected direction for the track record. If they are the same, the MULTIPLIER is set to 10. Otherwise, the MULTIPLIER is set to 1.

2) Calculate the percent of overlap between the sequence record 312 and the track record 314 as an integer between 0 and 100 by using the formula:

OVERLAP=(earliest endTime−latest startTime)/(latest endTime−earliest startTime)

If OVERLAP is <0, then set the OVERLAP to 0.

3) Calculate the match quality score by using the following formula:

SCORE=OVERLAP×MULTIPLIER

The counting system 230 populates the scoreboard 360 by iterating over the sequence records 312 that populate the sequence array 352 referenced by the top level 372 and for each of the sequence records 312, the counting system 230 also iterates over the track records 314 that populate the track array 354 referenced by the bottom level 374 and generates match quality scores 380 for each of the track records 314. As exemplified in FIG. 18A, once match quality scores 380 are generated and inserted as values 376 in the bottom level 364, each match quality score 380 for each track record 314 is compared to a bestScore value and if the match quality score 380 is greater than the bestScore value, the bestScore value is updated to reflect the higher match quality score 380. The bestTrack reference is also updated to reflect the track record 314 associated with the higher bestScore value.

As shown in FIG. 18B, once the bestTrack for the first sequence in the match record is determined, the counting system 230 iterates over the keys 370 for the top level 372 to determine the bestSequence, which reflects the sequence record 312 that holds the best match for the bestTrack, i.e., the sequence record/track record combination with the highest match quality score 380. The bestScore and bestSequence values are updated to reflect this determination. When the bestTrack and bestSequence values have been generated, the sequence record 312 associated with the bestSequence is deleted from the scoreboard 360 and the bestTrack value is set to 0 in all remaining keys 372 for the bottom level 364. The counting system 230 continues to evaluate the remaining sequence records 312 and track records 314 that make up the top and bottom levels 362, 364 of the scoreboard 360 until all sequence records 312 and track records 314 that populate the match record 316 have been matched and removed from the scoreboard 360, or until all remaining sequence records 312 have match quality scores 380 that are less than or equal to 0, i.e., no matches remain to be found. As shown in Table 1, the information related to the matching sequence records 312 and track records 314 may be used to prepare reports that allow employers to track, among other things, (i) how many times an employee enters or exits an access point; (ii) how many times an employee enters or exits an access point with a customer or anonymous object 320; (iii) the length of time that an employee or defined object 322 spends outside; and (iv) how many times a customer enters or exits an access point. This information may also be used to determine conversion rates and other "What If" metrics that relate to the amount of interaction employees have with customers. For example, as shown in Table 2, the system 210 defined herein may allow employers to calculate, among other things: (a) fitting room capture rates; (b) entrance conversion rates; (c) employee to fitting room traffic ratios; and (d) the average dollar spent. These metrics may also be extrapolated to forecast percentage sales changes that may result from increases to the fitting room capture rate, as shown in Table 3.

In some cases, there may be more than one counter 222, which consists of the combination of both the image capturing device 220 and the reader device 225, to cover multiple access points. In this case, separate sequence arrays 352 and track arrays 354 will be generated for each of the counters 222. In addition, a match array 318 may be generated and may comprise each of the match records 316 associated with each of the counters 222. In order to make optimal matches, tag history must be shared between all counters 222. This may be handled by merging, in a time-sorted order, all of the match records in the match array 318 and by using a single history map structure, which is generally understood by those with skill in the art. When matches are made within the match array 318, the match is reflected in the track array 354 associated with a specific counter 222 using the sequence array 352 associated with the same counter 222. This may be achieved in part by using a counter ID field as part of the track records 314 that make up the track array 354 referenced by the bottom level 364 of the scoreboard 360. For example, references to the track arrays 354 may be added to a total track array 356 and indexed by counter ID. The sequence arrays 352 would be handled the same way.

As shown in FIG. 19, a further embodiment of the present invention may be employed and may comprise a system 1210 having one or more sensors 1220, a data capturing device 1225 and a counting system 1230. In the illustrated embodiment, the sensor(s) 1220 may be image capturing devices and may be mounted above an entrance or entrances 1221 to a facility 1223 for capturing images from the entrance or entrances 1221 and object data 1261. The area captured by the sensor 1220 is a field of view 1244. Each image captured by the sensor 1220, along with the time when the image is captured, is a frame 1248. As described above with respect to image capturing device 20 in connection with a separate embodiment of the present invention, the sensor 1220 may be video based. The object data 1261 may include many different types of information, but for purposes of this embodiment of the present invention, it includes information indicative of a starting frame, an ending frame, and direction. It should be understood that the sensor 1220 may also employ other technology, which is widely known in the industry. Therefore, the manner in which object data 1261 is captured is not meant to be limiting so long as the sensor 1220 has the ability to track objects in time across a field of view 1244.

For exemplary purposes, the sensor 1220 may include at least one stereo camera with two or more video sensors 1246 (similar to the sensor shown in FIG. 2), which allows the camera to simulate human binocular vision. A pair of stereo images comprises frames 1248 taken by each video sensor 1246 of the camera. The sensor 1220 converts light images to digital signals through which the counting system 1330 obtains digital raw frames 1248 comprising pixels. Again, the types of sensors 1220 and video sensors 1246 should not be considered limiting, and it should be obvious that any sensor 1220, including image capturing devices, thermal sensors and infrared video devices, capable of counting the total foot traffic and generating a starting frame, an ending frame, and a direction will be compatible with the present system and may be adopted.

For providing more robust tracking and counting information, the object data 1261 from the sensor 1220 may be

combined with subset data **1226** that is captured by the data capturing device **1225**. The subset data **1226** may include a unique identifier **1232**A, an entry time **1232**B, an exit time **1232**C and location data **1262** for each object of interest **1258**. The subset data **1226** may be generated by data capturing devices **1225** that utilize various methods that employ doorway counting technologies, tracking technologies and data association systems. Doorway counting technologies, such as Bluetooth and acoustic based systems, are similar to the RFID system described above and generate subset data **1226**. To generate the subset data **1226**, the doorway counting technology may provide a control group with a device capable of emitting a particular signal (i.e., Bluetooth or sound frequency). The system may then monitor a coverage area **1228** and count the signals emitted by the devices associated with each member of the control group to generate subset data **1226**. The subset data **1226** from the doorway counting system may be combined with the object data **1261** from the sensor **1220** to generate counts related to anonymous objects and defined objects. The doorway counting system may also be video based and may recognize faces, gender, racial backgrounds or other immutable characteristics that are readily apparent.

The data capturing device **1225** may also use tracking technology that triangulates on a cellular signals emitted from a mobile handsets **1227** to generate location data **1262**. The cellular signal may be T-IMSI (associated with GSM systems), CDMA (which is owned by the CDMA Development Group), or Wi-Fi (which is owned by the Wi-Fi Alliance) signals. The data capturing device **1225** may also receive location data **1262**, such as GPS coordinates, for objects of interest from a mobile handset **1227**. The location data **1262** may be provided by a mobile application on the mobile handset or by the carrier for the mobile handset **1227**. User authorization may be required before mobile applications or carriers are allowed to provide location data **1262**.

For ease of reference, we will assume that the subset data **1226** discussed below is based on the location data **1262** that is provided by a mobile handset **1227**. The data capturing device **1225** receives subset data **1226** associated with a mobile handset **1227**, which is transmitted at a fixed time interval. The time interval for the present invention will typically be between 1 and 10 times per second, but it should be obvious that other time intervals may be used as well. In addition, the techniques for transmitting and receiving the signals from mobile handsets are well known by those with skill in the art, and various methods may be employed in the present invention without departing from the teachings herein. To ensure that the subset data **1226** for all mobile handsets **1227** is captured, the data capturing device **1225** may run continuously and independently of the other devices and systems that form the system **1210**. As mentioned above, the data capturing device **1225** may employ various types of signals without departing from the scope of this application. It is significant, however, that the data capturing device **1225** has the ability to track mobile handsets **1227**, or other similar devices, in time across a coverage area **1228**. The area captured by the data capturing device **1225** is the coverage area **1228**. In some instances, the field of view **1244** for the sensor may be entirely within the coverage area **1228** for the data capturing device **1225** and vice versa.

The data capturing device **1225** may also use data association systems **1245**. Data association systems **1245** take data from other independent systems such as point of sale systems, loyalty rewards programs, point of sale trigger information (i.e., displays that attach cables to merchandise and count the number of pulls for the merchandise), mechanical turks (which utilize manual input of data), or other similar means. Data generated by data association systems **1245** may not include information related to direction, but it may include more detailed information about the physical characteristics of the object of interest.

The counting system **1230** may process digital raw frames **1248**, detect and follow objects of interest ("objects") **1258**, and may generate tracks associated with objects **1258** in a similar manner as the counting system **30** described above. The counting system **1230** may be electronically or wirelessly connected to at least one sensor **1220** and at least one data capturing device **1225** via a local area or wide area network. Although the counting system **1230** in the present invention is located remotely as part of a central server, it should be evident to those with skill in the art that all or part of the counting system **1230** may be (i) formed as part of the sensor **1220** or the data capturing device **1225**, (ii) stored on a "cloud computing" network, or (iii) stored remotely from the sensor **1220** and data capturing device **1225** by employing other distributed processing techniques. In addition, the data capturing device **1225**, the sensor **1220**, and the counting system **1230** may all be integrated in a single device. This unitary device may be installed anywhere above the entrance or entrances to a facility **1223**. It should be understood, however, that the hardware and methodology that is used for detecting and tracking objects is not limited with respect to this embodiment of the present invention. Rather, it is only important that objects are detected and tracked and the data associated with objects **1258** and tracks is used in combination with subset data **1226** from the data capturing device **1225** to separately count and track anonymous objects **1320** and defined objects **1322**, which are associated with the mobile handset **1227**.

To transmit subset data **1226** from the data capturing device **1225** to a counting system **1230**, the data capturing device **1225** may be connected directly to the counting system **1230** or the data capturing device **1225** may be connected remotely via a wireless or wired communications network, as are generally known in the industry. It is also possible that the data capturing device **1225** may send subset data **1226** to the sensor **1220**, which in turn transmits the subset data **1226** to the counting system **1230**. The subset data **1226** may be comprised of various information, but for purposes of the present invention, the subset data **1226** includes a unique identifier, location based information and one or more timestamps.

To allow the counting system **1230** to process traffic data **1260**, subset data **1226** and object data **1261** may be pulled from the data capturing device **1225** and the sensor **1220**, respectively, and transmitted to the counting system **1230**. It is also possible for the data capturing device **1225** and the sensor **1220** to push the subset data **1226** and object data **1261**, respectively, to the counting system **1230**. It should be obvious that the traffic data **1260**, which consists of both subset data **1226** and object data **1261**, may also be transmitted to the counting system via other means without departing from the teachings of this invention. The traffic data **1260** may be sent as a combination of both subset data **1226** and object data **1261** and the traffic data **1260** may be organized based on time.

The counting system **1230** separates the traffic data **1260** into subset data **1226** and object data **1261**. To further process the traffic data **1260**, the counting system **1230** may include a listener module **1310** that converts the subset data **1226** into sequence records **1312** and the object data **1261** into track records **1314**. Moreover, the counting system **1230** may create a sequence array **1352** comprised of all of the sequence

records **1312** and a track array **1354** comprised of all of the track records **1314**. Each sequence record **1312** may consist of (1) a unique ID **1312***a*, which may be an unsigned integer associated with a mobile handset **1227**, the telephone number associated with the mobile handset **1227** or any other unique number, character, or combination thereof, associated with the mobile handset **1227**; (2) a startTime **1312***b*, which may consist of information indicative of a time when the mobile handset **1227** was first detected within the coverage area **1228**; (3) an endTime, which may consist of information indicative of a time when the mobile handset **1227** was last detected within the coverage area **1228** of the data capturing device **1225**; and (4) an array of references to all tracks that overlap a particular sequence record **1312**. Each track record **1314** may include (a) a counter, which may be a unique ID representative of a sensor **1220** associated with the respective track; (b) a direction, which may consist of information that is representative of the direction of movement for the respective track; (c) startTime, which may consist of information indicative of a time when the object of interest was first detected within the field of view **1244** of the sensor **1220**; (d) endTime, which may consist of information indicative of a time when the object of interest left the field of view **1244** of the sensor **1220**; and (e) handsetID, which (if non-zero) may include an unsigned integer identifying a mobile handset **1227** associated with this track record **1314**.

To separate and track anonymous objects **1320** (i.e., shoppers or random customers) and defined objects **1322** (such as shoppers with identified mobile handsets **1227** or shoppers with membership cards, employee badges, rail/air tickets, rental car or hotel keys, store-sponsored credit/debit cards, or loyalty reward cards, all of which may include RFID chips), the counting system **1230** for the system must determine which track records **1314** and sequence records **1312** match one another and then the counting system **1230** may subtract the matching track records **1314** from consideration, which means that the remaining (unmatched) track records **1314** relate to anonymous objects **1320** and the track records **1314** that match sequence records **1312** relate to defined objects **1322**. The steps related to matching track records **1314** and sequence records **1312** are described in detail above. A similar method for matching track records **1314** and sequence records **1312** may be employed in connection with the present embodiment of the counting system **1230**. The match algorithm or quality score algorithm that is employed should not be viewed as limiting, as various methods for matching tracks and sequence records **1314**, **1312** may be used.

In some cases, there may be more than one counting system **1230**, which consists of the combination of both the sensor **1220** and the data capturing device **1225**, to cover multiple access points. In this case, separate sequence arrays **1352** and track arrays **1354** will be generated for each of the counters **1222**. In addition, a match array **1318** may be generated and may comprise each of the match records **1316** associated with each of the counting systems **1230**. In order to make optimal matches, tag history must be shared between all counting systems **1230**. This may be handled by merging, in a time-sorted order, all of the match records in the match array **1318** and by using a single history map structure, which is generally understood by those with skill in the art.

By identifying, tracking and counting objects **1258** simultaneously with one or more sensors **1220** and one or more data capturing devices **1225**, the system **1210** can generate data sets based on time, geography, demographic characteristics, and behavior. For example, the system **1210** may be capable of determining or calculating the following:

a. The actual length of time the overall population or subsets of the population dwell at specified locations;
b. The actual time of entry and exit for the overall population and subsets of the population;
c. The overall density of the overall population and subsets of the population at specified points in time;
d. How time of day impacts the behaviors of the overall population and subsets of the population;
e. The actual location and paths for subsets of the population;
f. The actual entry and exit points for subsets of the population;
g. The density of subsets of the population;
h. Whether the geography or location of departments or products impacts the behaviors of subsets of the population;
i. The actual demographic and personal qualities associated with the subset of the population;
j. How demographic groups behave in particular geographic locations, at specified times or in response to trigger events, such as marketing campaigns, discount offers, video, audio or sensory stimulation, etc.;
k. The overall density of various demographic groups based on time, geography or in response to trigger events;
l. How the behavior of demographic groups changes based on time, geography or in response to trigger events;
m. Any data that may be generated in relation to subsets of the population may also be used to estimate similar data for the overall population;
n. Data captured for specific areas, zones or departments may be dependent upon one another or correlated; and
o. Combinations of the foregoing data or reports.

Although there are a multitude of different data types and reports that may be calculated or generated, the data generally falls into the following four dimensions **1380**: time **1380**A, geographic **1380**B, demographic **1380**C and behavioral **1380**D. These various dimensions **1380** or categories should not, however, be viewed as limiting as it should be obvious to those with skill in the art that other dimensions **1380** or data types may also exist.

To generate data related to the time dimension **1380**A, various algorithms may be applied. For example, the algorithm in FIG. **20** shows a series of steps that may be used to calculate dwell time **1400** for one or more shoppers or to count the frequent shopper data or number of visits **1422** by one or more shoppers. As shown at step **2110**, to calculate dwell time **1400** or frequent shopper data **1420**, the system **1210** must first upload the traffic data **1260**, including the object data **1261** and the subset data **1226**. The traffic data **1260** may also include a unique ID **1312**A, a start time **1312**B and an end time **1312**C for each shopper included as part of the traffic data **1260**. The start times **1312**B and end times **1312**C may be associated with specific predefined areas **1402**. To generate reports for specific time periods **1313**, the system **1210** may also sort the traffic data **1260** based on a selected time range. For example, at step **2120** the system **1210** may aggregate the traffic data **1260** based on the start time **1312**B, the end time **1312**C or the time period **1313**. Aggregating traffic data **1260** based on start time **1312**B, end time **1312**C or time period **1313** is generally understood in the industry and the order or specific steps that are used for aggregating the traffic data **1260** should not be viewed as limiting. Once the traffic data **1260** is aggregated or sorted, it may be used to calculate dwell times **1400** or frequent shopper data **1420**. It

should be understood that the time periods **1313** may be based on user-defined periods, such as minutes, hours, days, weeks, etc.

To allow a user to generate either dwell time **1400** or frequent shopper data **1420**, the system **1210** may ask the user to select either dwell time **1400** or frequent shopper data **1420** (see step **1230**). This selection and other selections that are discussed throughout this description may be effectuated by allowing a user to select a button, a hyperlink or an option listed on a pull-down or pop-up menu, or to type in the desired option in a standard text box. Other means for selecting reporting options may also be employed without departing from the present invention. To calculate the dwell time **1400** for a shopper, the following equation may be used:

Dwell time=(Time at which a shopper leaves a predefined area)−(Time at which a shopper enters a predefined area)

For example, assume a shopper enters a predefined area **1402**, such as a store, at 1:00 pm and leaves at 1:43 pm. The dwell time **1400** would be calculated as follows:

Dwell time=1:43−1:00=43 minutes

In this instance, the dwell time **1400** would be the total amount of time (43 minutes) that was spent in the predefined area **1402**. The predefined area **1402** may be defined as a specific department, i.e., the men's clothing department, the women's clothing department, a general area, a particular display area, a point of purchase, a dressing room, etc. Thus, if a shopper visits multiple predefined areas **1402** or departments, the system **1210** may calculate dwell times for each predefined area **1402** or department that is visited.

Predefined areas **1402** may be determined by entering a set of boundaries **1404** obtained from a diagram **1406** of the desired space or store. The set of boundaries **1404** may define particular departments, display areas within particular departments or other smaller areas as desired. More specifically, the predefined areas **1402** may be determined by copying the diagram **1406** into a Cartesian plane, which uses a coordinate system to assign X and Y coordinates **1408** to each point that forms a set of boundaries **1404** associated with the predefined areas **1402**. Track records **1314** may be generated for each shopper and may include an enter time **1410** and exit time **1412** for each predefined area **1402**. In order to calculate dwell times **1400**, the following information may be necessary: (i) unique IDs **1312**A for each shopper; (ii) a set of boundaries **1404** for each predefined area **1402**; (iii) coordinates **1408** for set of boundaries **1404** within a predefined areas **1402**; (iv) enter times **1410** and exit times **1412** for each predefined area **1402** and shopper. In addition to aggregating the traffic data **1260** and prior to calculating the dwell times **1400**, the system **1210** may also sort the traffic data **1260** by time periods **1313**, unique IDs **1312**A, and/or the predefined areas **1402** visited within the time periods **1313**. The process of calculating dwell times **1400** is an iterative and ongoing process, therefore, the system **1210** may store dwell times **1400** by shopper or predefined area **1402** for later use or use in connection with other dimensions **1380**. Dwell times **1400** may be used to generate reports that list aggregate or average dwell times **1400** for selected shoppers, geographies, time periods or demographic groups and these reports may also be feed into other systems that may use the dwell time **1400** to function, such as HVAC systems that may raise or lower temperatures based on the average dwell times **1400** for various time periods and geographic locations. It should be obvious to those with skill in the art that the dwell times **1400** and the dwell time reports **1400**A may be used in many different ways. Therefore, the prior disclosure should be viewed as describing exemplary uses only and should not limit the scope potential uses or formats for the dwell times **1400** or dwell time reports **1400**A.

To generate frequent shopper data **1420**, the system **1210** may first upload shopper visit data **1450** for a particular time period **1313**. Shopper visit data **1450** may be generated from the dwell times **1400** for a predefined area **1402** without regard to the length of the time associated with the dwell times **1400**. In other words, step **2134** may increment a counter **1454** for each shopper that enters a predefined area **1402**. Then the system **1210** may populate the shopper visit data **1450** with the data from the counter **1454** and store the shopper visit data **1450** in a database **1452**. The database **1452** may sort the shopper visit data **1450** based on a unique ID **1312**A for a particular shopper, a predefined area **1402**, or a desired time period **1313**. To avoid including walk-through traffic as part of the shopper visit data **1450**, the system **1210** may require a minimum dwell time **1400** in order to register as a visit and thereby increment the counter **1454**. The minimum dwell time **1400** may be on the order of seconds, minutes, or even longer periods of time. Similar to dwell times **1400**, the shopper visit data **1450** may be sorted based on time periods **1313**, unique IDs **1312**A, and/or the predefined areas **1402**. For example, as shown in step **2136**, the shopper visit data **1450** may be used to generate a shopper frequency report **1450**A by geography or based on a predefined area **1402**. More specifically, the shopper frequency report **1450**A may show information such as the percentage of repeat shoppers versus one-time shoppers for a given time period **1313** or the distribution of repeat shoppers by predefined areas **1402**. The shopper frequency report **1450**A may also disclose this information based on specified demographic groups. It should be obvious to those with skill in the art that the shopper visit data **1450** and the shopper frequency reports **1450**A may be used in many different ways. Therefore, the prior disclosure should be viewed as describing exemplary uses only and should not limit the scope potential uses or formats for the shopper visit data **1450** or shopper frequency reports **1450**A.

To generate data related to the geographic dimension **1380**B, several different methods may be employed. The algorithm shown in FIG. **21** shows one example of a series of steps that may be used to analyze foot traffic by geography. After it is determined in step **2200** that the geographic analysis should be conducted, the system **1210** must first upload the traffic data **1260**, including the object data **1261**, and the subset data **1226**. The subset data **1226** includes a unique identifier **1232**A, an entry time **1232**B, an exit time **1232**C and location data **1262** for each object of interest **1258**. The location data **1262** for object of interests **1258** is particularly important for generating data related to the geographic dimension **1380**B. As mentioned above, the location data **1262** may be generated by using information from fixed receivers and a relative position for a shopper to triangulate the exact position of a shopper within a predefined area **1402** or by receiving GPS coordinates from a mobile handset. The exact position of a shopper within a predefined area **1402** is determined on an iterative basis throughout the shopper's visit. Other methods for calculating exact position of a shopper may also be used without departing from the teachings provided herein.

To determine the position of an object of interest **1258** within a predefined area **1402**, the location data **1262** may be associated with the predefined area **1402**. As mentioned above, the predefined area **1402** may be defined by entering a set of boundaries **1404** within a diagram **1406** of the desired space or store. The diagram **1406** of the desired space or store

may be generated by the system **1210** from an existing map of the desired space or store. Again, as referenced above, boundaries **1404** may be generated by copying the diagram **1406** into a Cartesian plane and assigning X and Y coordinates **1408** to each point that forms an external point on one or more polygons associated with the predefined area **1402**. By iteratively tracking the position of an object of interest **1258** over time, the system **1210** may also generate the direction **1274** in which the object of interest **1258** is traveling and path data **1272** associated with the path **1271** traveled by the object of interest **1258**. The position of an object of interest **1258** within a predefined area **1402** may also be generated by: (1) using fixed proximity sensors that detect nearby objects of interest **1258**, (2) triangulation of multiple reference signals to produce the position of an object of interest **1258**, or (3) using cameras that track video, infrared or thermal images produced by an object of interest **1258**. Other means for generating the position of an object of interest **1258** may also be used without departing from the teachings herein.

To generate path data **1272** for an object of interest **1258**, the system **1210** may use subset data **1226**, including location data **1262**, associated with an object of interest **1258** to iteratively plot X and Y coordinates **1408** for an object of interest **1258** within a predefined area **1402** of a diagram **1406** at sequential time periods. Therefore, the X and Y coordinates **1408** associated with an object of interest **1258** are also linked to the time at which the X and Y coordinates **1408** were generated. To count and track objects of interest **1258** in predefined areas **1402** that are comprised of multiple floors, subset data **1226** and/or location data **1262** may also include a Z coordinate **1408** associated with the floor on which the object of interest **1258** is located. A multi-floor diagram is shown in FIG. **22**.

As shown in step **2220**, after location data **1262** and path data **1272** are generated for objects of interest **1258**, that information should be stored and associated with the respective objects of interest **1258**. As shown in step **2230**, the system **1210** allows a user to analyze traffic data **1260** based on a predefined area **1402** or by path data **1272** for objects of interest **1258**. The predefined area **1402** may be a particular geographic area, a mall, a store, a department within a store, or other smaller areas as desired. To analyze the traffic, the system **1210** may first aggregate the traffic data **1260** for the objects of interest **1258** within the predefined area **1402** (see step **2232**). As shown in step **2234**, the system **1210** may subsequently load dwell times **1400**, shopper visit data **1450**, sales transaction data **1460** or demographic data **1470** for the objects of interest **1258**. Step **2236** generates store level traffic data **1480** for predefined areas **1402** by extrapolating the subset data **1226** for particular predefined areas **1402** based on the corresponding object data **1261**, which may include the total number of objects of interest **1258** within a predefined area **1402**. By using the traffic data **1260**, which includes object data **1261** and subset data **1226**, and as shown in Step **2238**, the system **1210** may generate reports that show the number of objects of interest **1258** for a predefined area **1402**, the number of objects of interest for a predefined area **1402** during a specific time period **1313**, the number of predefined areas **1402** that were visited (such as shopper visit data **1420**), or the dwell times **1400** for predefined areas **1402**. These reports may include information for specific subsets of objects of interest **1258** or shoppers, or the reports may include store level traffic data **1480**, which extrapolates subset data **1226** to a store level basis. It should be obvious that the reports may also include other information related to time, geography, demographics or behavior of the objects of interest **1258** and therefore, the foregoing list of reports should not be viewed as limiting the scope of system **1210**.

At step **2230**, the user may also choose to analyze traffic data **1260** based on path data **1272** for objects of interest **1258** or the path **1271** taken by objects of interest **1258**. To analyze the traffic data **1260** based on path data **1272** or the path **1271** taken, the system **1210** may first load the location data **1262** and path data **1272** that was generated for objects of interest **1258** in step **2210**. The system **1210** may also load information, such as dwell times **1400**, shopper visit data **1450**, sales transaction data **1460** or demographic data **1470** for the objects of interest **1258**. Once this information is loaded into system **1210**, the system **1210** may aggregate the most common paths **1271** taken by objects of interest **1258** and correlate path data **1272** information with dwell times **1400** (see step **2244**). After the information is aggregated and correlated, various reports may be generated at step **2246**, including reports that show (i) the most common paths that objects of interest take in a store by planogram, including corresponding dwell times if desired, (ii) changes in shopping patterns by time period or season, and (iii) traffic patterns for use by store security or HVAC systems in increasing or decreasing resources at particular times. These reports may be stored and used in connection with generating data and reports for other dimensions **1380**. As shown in FIGS. **23** and **24**, reports may also be generated based on the behavioral and demographic dimensions **1380**C, **1380**D.

To generate data related to the demographic dimension **1380**C, the algorithm shown in FIG. **23** may be employed. As shown at step **2300** in FIG. **23**, the system **1210** should first load traffic data **1260** and demographic data **1500**. The demographic data **1500** may be received from a retail program, including loyalty programs, trigger marketing programs or similar marketing programs, and may include information related to a shopper, including age, ethnicity, sex, physical characteristics, size, etc. The traffic data **1260** may be sorted in accordance with the demographic data **1500** and other data, such as start time **1312**B, end time **1312**C, time period **1313** and location data **1262**. Once the traffic data **1262** and demographic data **1500** is loaded and sorted, the system **1210** may analyze the traffic data **1260**, including the object data **1261** and subset data **1226** based on various demographic factors, including, but not limited to, shopper demographics, in-store behavior and marketing programs.

To analyze the traffic data **1260** based on the shopper demographics (step **2320**), the system **1210** may sort the traffic data **1260** by geography and time period. It should be obvious, however, that the traffic data **1260** may also be sorted according to other constraints. In step **2322**, the system **1210** analyzes the traffic data **1260**, including object data **1261** and subset data **1226**) based on time periods **1313** and predefined areas **1402**. The analysis may include counts for objects of interest **1258** that enter predefined areas **1402** or counts for objects of interest **1258** that enter predefined areas **1402** during specified time periods **1313**. To assist in analyzing the traffic data **1260** based on time periods **1313** and predefined areas **1402**, the information that was generated in connection with the time dimension **1380**A, including dwell times **1400**, shopper data **1420** and shopper visit data **1450**, and the geographic dimension **1380**B, i.e., predefined areas **1402**, boundaries **1404** and x and y coordinates, may be used. As shown in step **2324**, the system **1210** may generate reports that show traffic by demographic data **1500** and store, department, time of day, day of week, or season, etc.

To analyze traffic data **1260** based on in-store behavior, the system **1210** must determine whether to look at in-store behavior based on dwell time **1400** or path data **1272**. If dwell

time is selected (step **2336**), the system **1210** may load dwell times **1400** generated in relation to the time dimension **1380**A and sort the dwell times **1400** based on the geographic dimension **1380**B. After the dwell times **1400** and path data **1272** are combined with the demographic data **1500**, the system **1210** may generate reports that show the dwell times **1400** by profile characteristics or demographic data **1500**, i.e., age, ethnicity, sex, physical characteristics, size, etc. For analyzing traffic data **1260** based on a combination of demographic data **1500** and path data **1272**, the system **1210** may first load path data **1272** generated in relation to the geographic dimension **1380**B. After the path data **1272** is sorted according to selected demographic data **1500**, the system **1210** may then generate reports that show the number of departments visited by objects of interest **1258** associated with particular demographic groups, the most common paths used by the objects of interest **1258** associated with those demographic groups. It should be obvious that other reports associated with demographic groups and path data **1272** may also be generated by the system **1210**.

To analyze the traffic data based on a particular marketing program, the system **1210** may first load demographic data **1500** associated with a particular marketing program **1510**. The marketing program **1510** may be aimed at a specific product or it may be a trigger marketing program being offered by a retailer. Examples of such programs are: "percent-off" price promotion for items in a specific department; e-mail "blasts" sent to customers promoting certain products; time-based discounted upsell offerings made available to any female entering the store; a "flash loyalty" discount for any customer making a return trip to the store within a 10-day period; upon entering the store sending a shopper a message informing her of a trunk show event taking place later that day; and provide shoppers with the option to download an unreleased song from a popular band made available as part of national ad campaign. Other types of marketing programs **1510** may also be the source of the demographic data without departing from the teaching and tenets of this detailed description. To analyze the traffic data based on the marketing program **1510**, the system **1210** may first sort the traffic data **1260** based on the demographic data **1500** provided by the marketing programs. As shown in step **2342**, the system **1210** may then generate reports that show retailer loyalty program driven behavior demographics, such as the impact of loyalty programs on particular demographic groups, the traffic of those demographic groups or shopping habits of those demographic groups. These reports may include: information related to how specific demographic groups (teens, young adults, seniors, males, females, etc.) shop in specific departments or areas of a store; traffic reports with information related to before and after a targeted promotion is offered to "loyal" customers; benchmark information regarding the effects of marketing programs on traffic and sales within the store; and comparisons of traffic by department for a targeted demographic promotion.

To generate data related to the behavioral dimension **1380**D, the system **1210** may combine data and reports generated in connection with the other dimensions **1380**, namely, the time dimension **1380**A, geographic dimension **1380**B and demographic dimension **1380**C. In addition, conversion rate analysis or purchaser/non-purchaser analysis may also be added to the data and reports generated in connection with the other dimensions **1380**. To generate conversion rates **1600**, purchase data **1610**, which includes purchaser **1610**A and non-purchaser data **1610**B, the algorithm shown in FIG. **24** may be employed. As shown at step **2400** in FIG. **24**, the first step is to determine whether to generate conversion rates **1600** or purchase data **1610**.

For generating conversion rates **1600**, the system may first load traffic data **1260** and transaction data **1620** from the geographic dimension **1380**B and sort the traffic data **1260** by time periods **1313**. The transaction data **1620** may include information related to the sales amount, the number of items that were purchased, the specific items that were purchased, the date and time of the transaction, the register used to complete the transaction, the location where the sale was completed (department ID and sub-department ID), and the sales associate that completed the sale. Other information may also be gathered as part of the transaction data **1620** without departing from the teaching herein. Next, the system **1210** may load projected traffic data from the geographic dimension **1380**B, which is also sorted by time periods **1313**. In step **2414**, the system **1210** may calculate conversion rates **1600**. The conversion rates may be calculated by dividing the transactions by the traffic counts within a predefined area **1402** by a time period **1313**. For instance, for one hour of a day a department in a store generated twenty sales (transactions). During the same hour, one hundred people visited the department. The department's conversion rate was twenty percent (20%) (20 transactions/100 shoppers). The conversion rates **1600** may also be associated with a demographic factor **1630**. For instance, given the type of store, males or females (gender demographic) may convert at different rates. The conversion rates **1600** that are calculated may be stored by the system **1210** for later use in step **2416**. Once the conversion rates **1600** are calculated, they may be used to generate reports such as the conversion rate **1600** for an entire store or a specific department, the conversion rate **1600** for shoppers with specific profiles or characteristics, cross-sections of the above-referenced conversion rates **1600** based on a time period **1313**, or other reports based on combinations of the conversion rate **1600** with information from the time dimension **1380**A, geographic dimension **1380**B or demographic dimension **1380**C.

For generating reports based on purchaser behavior, the system **1210** may first load dwell times **1400** and then sort the dwell times **1400** by predefined areas **1402** (see step **2420**). The dwell times **1400** may be further sorted by time periods **1313**. As shown in step **2422**, the system **1210** may then load transaction data **1620** (such as sales transactions) for the same predefined areas **1402** and corresponding time periods **1313**. The system **1210** may then produce reports that show comparisons between purchasers and non-purchasers based on dwell times **1400**, predefined areas **1402** and/or time periods **1313**. These reports may also be sorted based on demographic data **1470**, as mentioned above.

The invention is not limited by the embodiments disclosed herein and it will be appreciated that numerous modifications and embodiments may be devised by those skilled in the art. Therefore, it is intended that the following claims cover all such embodiments and modifications that fall within the true spirit and scope of the present invention.

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What is claimed is:

1. A method for counting and tracking defined objects, comprising the steps of:

receiving subset data with a data capturing device, wherein the subset data is associated with defined objects and includes a unique identifier, an entry time, an exit time, and location data for each defined object;

receiving subset data at a counting system;

counting the defined objects;

tracking the defined objects;

associating a location of a defined object with a predefined area;

generating path data by plotting X and Y coordinates for the defined object within the predefined area at sequential time periods; and

receiving location data at the data capturing device from tracking technology that detects cellular signals emitted from one or more mobile handsets.

2. The method of claim **1**, wherein the cellular signals includes T-IMSI, CDMA, or Wi-Fi signals.

3. The method of claim **1**, further including the step of receiving data from another independent system regarding physical characteristics of the object.

4. The method of claim **3**, wherein the other independent system is selected from the group consisting of point of sale systems, loyalty rewards systems, point of sale trigger information, and mechanical turks.

5. The method of claim **1**, further including the steps of converting the subset data into sequence records and creating a sequence array of all of the sequence records, wherein a sequence record comprises:

(a) a unique ID, which is an unsigned integer associated with a mobile handset, a telephone number associated with the mobile handset or any other unique number, character, or combination thereof, associated with object;

(b) a start time, which may consist of information indicative of a time when the object was first detected within a coverage area;

(c) an end time, which may consist of information indicative of a time when the object was last detected within the coverage area of the data capturing device; and

(d) an array of references to all tracks that overlap a particular sequence record.

6. The method of claim **1**, further including the step of determining a dwell time for an object within a predefined area by subtracting the end time for that predetermined area from the start time for that predetermined area.

7. The method of claim **1**, further including the step of using Z coordinates to further track objects within a predefined area defined by multiple floors.

8. The method of claim **1**, further including the step of using the subset data to generate reports showing at least one of the number of objects within a predefined area, a number of objects within the predefined area during a specific time period, a number of predefined areas that were visited by an object, or dwell times for one or more predefined areas.

9. The method of claim **1**, further including the step of using at least path data and subset data to aggregate the most common paths taken by objects and correlate path data information with dwell times.

10. The method of claim **9**, further including the step of generating a report that shows at least one of the following:

(a) the most common paths that objects take in a store, including corresponding dwell times;

(b) changes in shopping patterns by time period or season; and

(c) traffic patterns for use by store security or HVAC systems in increasing or decreasing resources at particular times.

11. The method of claim **1**, further including the step of generating a conversion rate by

(a) loading transaction data related to transactions performed;

(b) loading traffic data including a traffic count and sorting by time periods, and

(c) dividing the transactions by the traffic counts for the time periods.

12. The method of claim **11**, wherein the transaction data includes a sales amount, the number of items purchases, the specific items purchased, the data and time of the transaction, the register used for the transaction, and the sales associate that completed the transaction.

13. The method of claim **11**, further including the step of generating a report showing comparisons between purchasers and non-purchasers based on at least one of the dwell times, the predefined areas, or the time periods.

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